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NOTES ON BULBIFEROUS FUNGI WITH A KEY TO DESCRIBED SPECIES

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(WITH PLATES XXI–XXIII AND SIX FIGURES)

Introduction

As has been shown in a former article (**6**), the term bulbil, as applied to fungi, refers to reproductive bodies of more or less definite form, composed of a compact mass of homogeneous or heterogeneous cells which may be few or many in number, but which are usually developed from primordia of more than one cell. This mode of reproduction is common among certain fungi and constitutes the only known means among others. Many of these structures superficially resemble the "spore-balls" of *Urocystis* or *Tuburcinia* among the smuts, but differ from them in their manner of germination. In general appearance and mode of development the bulbils of *Papulospora spinulosa* Hotson might readily be taken for "spore-balls" of *Urocystis*, but, on germination, promycelia bearing sporidia such as are produced by the smuts are not formed, nor is the production of these structures ever associated with the germination of bulbils. Other bulbils resemble compound spores of the *Stemphilium* type, but the latter are the result of successive divisions of single cells, while bulbils are derived from a group of initial cells to which new ones are added by a process of gemmation rather than formed by the septation of a single cell. Although this is true in general, in compound spores like those of

Stephanoma strigosum Wallr. the superficial cells are produced in a manner similar to those of certain bulbils. Mature bulbils may also resemble sclerotia. The latter, however, may be regarded as the result of the irregular massing together of vegetative filaments, the individual cells of which do not partake of the nature of spores either in appearance or structure, while in the bulbil those cells that are filled with protoplasm usually act independently of each other, in this respect resembling spores. There are a number of sclerotia of the simpler type, such as are produced by *Penicillium italicum* and its allies, which are small and more or less regular in form and outline, somewhat resembling bulbils in appearance. The mode of development of these sclerotia, however, consists in the irregular massing together of the vegetative filaments, as has just been mentioned.

Before 1912 the literature relating to bulbils dealt with less than a dozen described forms. Most of these were referred either to the form genus *Papulospora* or to *Helicosporangium*. Owing to the fact that the limitations of these two genera were not clearly defined, it was thought wise to redescribe the genus *Papulospora* (**6**), and to group all those fungi that produced bulbils, but whose perfect condition had not been obtained, into this form genus. The literature on this subject has been carefully reviewed in the article already mentioned. This article shows clearly that these fungi do not belong to any one of the natural orders, nor do they in any sense form a group by themselves, but occur without regularity as imperfect forms among the main groups of higher fungi. The forms, associated with bulbiferous conditions mentioned in that article, include among the Discomycetes a new species of *Cubonia*, among the Hypocreales 3 species of *Melanospora;* among the Basidiomycetes at least 4 types; while 9 species of *Papulospora* as yet unconnected with a perfect form are added to those already known. Among the latter, also, *Papulospora candida* Sacc. was found to be definitely connected with a second and well marked imperfect form, namely *Verticillium agaricinum* (Link) Corda var. *clavisedum* Sacc.

In 1914 NEGER (**9**) referred to a bulbiferous condition in connection with the life history of *Melanospora marchica* Lindau.

According to his account, the bulbils resemble the compound spores of *Urocystis* among the Ustilaginales. The color of these *Urocystis*-like spores is reddish to chocolate brown, their form more or less spherical, the cortex being a layer of empty, colorless cells. The size of the spore balls, however, is not given. They apparently resemble the bulbils of *Melanospora papillata* Hotson, but the perithecia of the two species are different. In *M. marchica* the perithecium has no papilla, the setae arising from the flush surface of the wall. The perithecium of *M. papillata*, on the other hand, has a distinct and often quite prominent papilla, the terminal setae being produced at its tip. The bulbils of *M. marchica* also resemble those of *Papulospora coprophila* (Zukal) Hotson, but vary somewhat in their mode of development. Apparently NEGER had not seen the writer's article dealing with bulbils (**6**) or that of BAINIER (**1**), and therefore makes no comparisons.

Recently DODGE (**3, 4**) has reported a species of *Papulospora* closely associated with *Ascobolus magnificus* Dodge. He is of the opinion that this is either a parasite on or an asexual spore form of the *Ascobolus*. These bulbils are light brown, with a layer of empty cells forming the margin. A description of this fungus is given in the present article under the name of *Papulospora magnifica*.

It has been shown in a recent article by MELHUS, ROSENBAUM, and SCHULTZ (**8**) that a species of *Papulospora* producing bulbils is frequently associated with the powdery scab of potatoes (*Spongospora subterranea* [Wallr.] Johnson). These investigators have isolated *P. coprophila* (Zukal) Hotson from tubers infected with powdery scab. This organism has been shown by inoculation experiments to be entirely saprophytic and in no way responsible for the disease. They believe, however, that the presence of bulbils of a species of *Papulospora* associated with *Spongospora* in the same sorus has probably been largely responsible for the confusion found in the writings of earlier investigators who observed numerous fungous threads in the sori, and in some instances spore balls that were quite different from those of *Spongospora*.

The cultural methods used in the study of the forms under consideration were similar to those described in a former paper (**6**).

The substrata were put in moist chambers, and as the bulbils appeared they were picked out with sterilized dissecting needles and transferred to tubes containing nutrient material.

Description of species

Bulbils are in all cases to be regarded as imperfect conditions of higher fungi. As has already been indicated, some have been definitely connected with perfect conditions belonging to widely separated genera of both Ascomycetes and Basidiomycetes. Those, however, that are to be considered in the present article have thus far baffled every effort to induce them to produce any perfect form, even after 7 or 8 years of cultural study. Two of these are doubtless Basidiomycetes, since their mycelia possess clamp connections, while another shows some evidence that it belongs to the Pyrenomycetes. It is the aim of the present article to contribute further information regarding the occurrence, morphology, and development of bulbils, and also to bring together the described species in the form of a key to the genus *Papulospora*.

Papulospora pallidula, n.sp. (figs. 1–16; text fig. 2).—Mycelium white, procumbent, scanty on most media; bulbils colorless, becoming pale yellow when old, somewhat spherical, 70–100 μ in diameter, sometimes elongated to 140 μ; primordium of two kinds, one a short lateral branch which divides dichotomously of 3 or 4 orders, occasionally more, and the other a group of intercalary cells. No other means of reproduction at present known.

On gross cultures of dog dung from Guatemala and Claremont, California; also on rabbit dung from Ontario.

The substrata were put into moist chambers and, when the bulbils appeared, transfers were made, eventually producing pure cultures. This fungus has been kept growing for more than 7 years on many different kinds of media, such as bran, prune, potato, cornmeal agar, etc. Thus far, however, all efforts to induce it to produce any other fructification than bulbils have failed. The bulbils are readily distinguished by their pale color. On a clear substratum they are almost colorless, while on horse dung or other dark media they become slightly yellowish or cream colored. As

is true with many other fungi, the abundance of the mycelium depends largely upon the kind of substratum. On potato or goat dung agar it develops very sparingly, often becoming quite difficult to detect even with a good lens, while on bran or cornmeal agar it becomes more conspicuous, growing evenly over the whole surface of the culture and on the sides of the tubes, but never becoming very flocculent. On appropriate media such as horse dung, bran, or cornmeal agar, the mycelium forms a thick felted layer over the substratum. Most of the hyphae are small, about 3–5 μ in diameter, but some of the older ones become as large as 10 μ, with prominent cross walls. They are frequently packed with large oil globules (fig. 1). Here and there in the hyphae swollen cells appear that are full of food material. These are oval at first, but eventually become almost spherical.

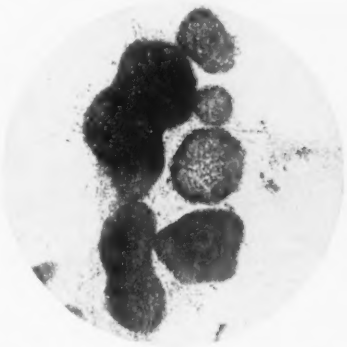


FIG. 1.—Group of bulbils of *P. byssina*, showing variations in size.

DEVELOPMENT OF BULBIL.—A short lateral branch divides dichotomously, producing dichotomies of the second, third, or sometimes of the fourth order (figs. 2–6). These branches divide into short cells which enlarge, eventually forming the central ones of the bulbil. As these cells grow they become more compact, and from them by a process of budding others are formed which increase in size, becoming closely and compactly pressed against their neighbors (figs. 7–9). This mode of development usually produces mature bulbils that are more or less spherical in form and measure 70–100 μ in diameter (fig. 13).

A second mode of development of the bulbil is sometimes observed. Intercalary cells become swollen, having absorbed a large quantity of food material. From these large cells others are produced by a process of gemmation, and these in turn bud off others and so on (figs. 10–12). Eventually a bulbil that is very

pale in color is formed, with several large cells in the center which are conspicuously filled with oil globules. These bulbils are usually more or less spherical, but not infrequently become elongated, as shown in text fig. 2, which shows a group of bulbils, the longest of which measures 78 by 140 μ and is probably the result of the fusing of two immature forms. These bulbils germinate readily in water. Fig. 13 shows a germinating bulbil 75 by 67.5 μ in diameter after 24 hours in a Van Tieghem cell. The young hyphae, which have a large number of oil globules, are usually produced from the larger cells, but any cell is capable of germination. Occasionally as the bulbils grow older the cells composing them adhere less firmly together, becoming more and more like independent spores (fig. 14). It requires only a slight pressure to force them apart. This resembles the condition found in connection with the development of the bulbil of *Papulospora polyspora* Hotson (**6**), which in turn suggests a similar condition found in *Aegerita webberi* Fawcett (**5**). Fig. 14 shows a few of these loosely connected cells germinating, which seem to act independently, like spores.

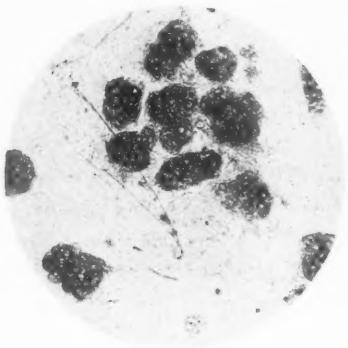


FIG. 2.—Group of bulbils of *P. pallidula*.

It is probable that one of the primordia just described is that of the perfect stage, but for some reason it fails to develop further. This view is strengthened by the fact that on several occasions perithecium-like structures over a millimeter in diameter have been found, as if an effort were being made by the fungus to produce the perfect stage. Thus far, however, none of these have been induced to develop sufficiently to produce spores.

Papulospora byssina, n.sp. (figs. 17–24; text fig. 1).—Mycelium white, procumbent, scanty on most media; bulbils light straw or cream colored, becoming brownish with age, more or less spherical

in form, 100–250 μ, occasionally elongated to 350 μ in diameter, produced in fluffy aerial clusters; primordium one or more short lateral branches twining spirally about the main branch. No other means of reproduction at present known.

On horse dung, Kittery, Maine; Seattle, Washington; St. Louis, Missouri.

The original material from which pure cultures of this fungus were obtained was found on a horse dung compost at Kittery, Maine, by Dr. THAXTER. It has since been found by the writer on similar material in the vicinity of Seattle; also on material sent from St. Louis, Missouri, by S. M. ZELLER. In the last instance the bulbils apparently were produced after the horse dung compost had been used as a fertilizer on mushroom beds. This fungus has never been found on any other substratum than horse dung. It has been grown on different media in pure cultures for 6 years without inducing it to produce any other fructification than bulbils.

The mycelium is white, 3–5 μ in diameter. It is usually procumbent, but when cultures are left in such a position that the hyphae can grow straight downward they grow out into the air, producing long streamers or festoons which attach themselves to the opposite side of the test tube.

The bulbils of *P. byssina* resemble those of *Grandinia crustosa*, but the two species can easily be distinguished by the prominent clamp connections in the mycelium of the latter. Even the general appearance of the mycelium in cultures is sufficient to distinguish them, *Grandinia* producing characteristic "white, fibrous, ropelike strands of hyphae which radiate conspicuously in all directions from the point of inoculation." This phenomenon is entirely absent in *P. byssina*. The cells composing the bulbils are homogeneous throughout. In this respect they resemble those of *P. sporotricoides* and *P. cinerea*, but in the former species the bulbils are small, 20–36 μ in diameter, and chocolate brown, while in the latter they are about the same size but steel gray. In *P. byssina*, however, the bulbils are large, 100–250 μ in diameter, and straw color.

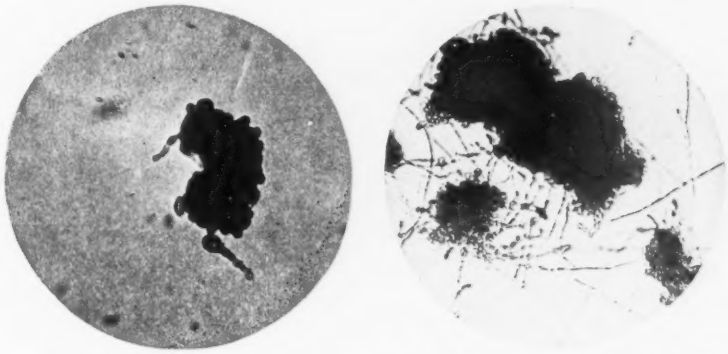
DEVELOPMENT OF BULBIL.—In most cases the primordium of the bulbil consists of a short lateral branch which may or may not divide dichotomously. This branch coils around the main hypha

(fig. 17), which may send out other lateral branches near the first (fig. 19). This branch may also take part in the formation of the bulbil. The cells of these various branches increase in size and become well supplied with food material. From them short lateral branches are produced which either intertwine among each other, or if very short assume the form of new cells as if produced by a process of budding or gemmation. Fig. 20 shows the primordium of a bulbil in which the secondary branches are being produced. These will eventually intertwine with each other in a more or less wormlike fashion, as shown in fig. 21, an immature bulbil 44 μ in diameter. The first lateral branches that twine around the primary filament may become localized, in which case the mature bulbils will be somewhat spherical, as shown in fig. 22, which represents a bulbil 110 μ in diameter. More often, however, the spherical bulbils are produced in a slightly different way. Not infrequently a terminal branch coils up and winds back on itself, or it may divide dichotomously, both branches thus formed twining back on the main filament (fig. 18). A primordium of this sort develops in the same way as the one already described, by the intertwining of lateral branches. The mature bulbil, however, tends to be more spherical than that in which a lateral branch twines about the primary filament. Occasionally several bulbils may be produced from the same filaments, as is indicated in fig. 24, which shows the beginnings of 3 bulbils at *a*, *b*, and *c* respectively. At *a* the secondary branches are beginning to be formed in a manner similar to that shown in fig. 20. It is possible that *a* and *b* will merge into one, forming an elongated and more or less irregular bulbil (text fig. 1). Owing to the variation in the mode of development, a great diversity of form is produced. Text fig. 1 represents a group of bulbils showing this wide variation of form. The exact dimensions of these bulbils vary from 112.5 to 338 μ, but occasionally even a greater difference than this is observed.

To test the germinating power of these fruiting bodies, hanging drops were made in Van Tieghem cells. It was found that in 24 hours many of them had begun to germinate, and in 48 hours numerous hyphae were developed. Fig. 23 represents a portion of a germinating bulbil after 48 hours.

Papulospora aurantiaca, n.sp. (figs. 25–38; text figs. 3, 4).—Mycelium white at first, becoming yellowish with age, procumbent, scanty on most media, densely filled with oil globules, clamp connections sparingly produced; bulbils pale yellow, becoming orange, nearly spherical, frequently aggregated, 100–250 μ in diameter; primordium a spiral of one or two turns. No other mode of reproduction at present known.

On bark collected by Dr. THAXTER near Port of Spain, Trinidad, W.I.



FIGS. 3, 4.—*P. aurantiaca:* fig. 3, mature bulbil; fig. 4, several germinating bulbils.

The mycelium of *Papulospora aurantiaca* is somewhat inconspicuous, the hyphae being small, usually about 2.5–3.5 μ in diameter, and scanty. On certain media, like cornmeal or bran agar, it becomes more marked but never profuse on any media tried. These included such nutrient material as potato, sugar, bran, cornmeal, prune juice, horse dung, various kind of wood, etc. The hyphae contain large numbers of oil globules which vary considerably in size. When the filaments are crushed these float out into the water, a number frequently fusing together and sometimes forming large spherical globules 17.5 μ or more in diameter.

Many and varied experiments have been made in the hope of causing the fungus to produce its perfect form, but thus far all efforts have failed. That it is a Basidiomycete is readily seen by the presence of clamp connections in the mycelium. These are

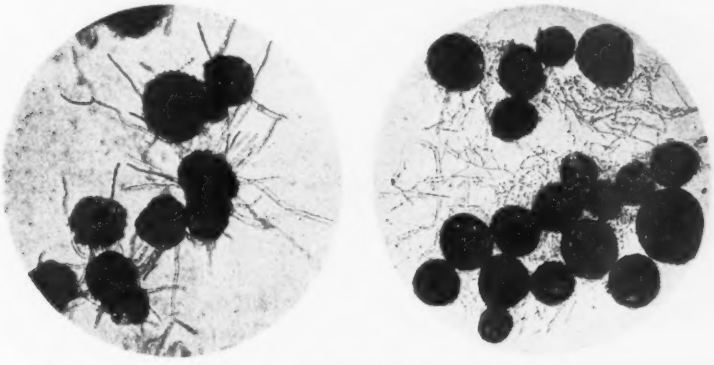
small, more or less inconspicuous, and sparingly developed. There are a number of basidiomycetous forms that produce bulbils as an imperfect condition. In a former contribution (**6**) the writer has referred to 4 such species, and in the present article 2 additional ones are described. The reddish orange color of the bulbil under consideration readily distinguished it from other species having clamp connections. The bulbils of *P. nigra* and *P. anomala* are dark brown or black, those of *Corticium alutaceum* chocolate brown, and those of *Grandinia crustosa* straw colored with conspicuous clamps.

Samples of the fruiting bodies of *Sporodesmium aurantiacum* B. and C., collected by Dr. THAXTER at Cranberry, North Carolina, in August 1889, were obtained from him for comparison with the bulbils of *P. aurantiaca*. As these structures were too old to germinate, a comparison of their mode of development could not be made. The fruiting bodies of the two fungi resemble each other so closely in their general form, color, texture, etc., however, that there is little doubt but that they are identical.

DEVELOPMENT OF BULBIL.—In common with many other bulbils, those of *P. aurantiaca* begin by a short lateral branch coiling up spirally. The early stages in the development, with some of the variations, are illustrated in figs. 25–38. During the process of coiling, which seldom results in more than two turns, the individual cells comprising the primordium become well supplied with food material and often appear distended (figs. 26, 27, 29). From the cells composing the coil short branches are developed (figs. 27, 28, 31, 32). These secondary branches may twine about each other or they may enlarge, forming cells that resemble those produced by a process of gemmation in other bulbils. These short branches and cells continue to be formed, sometimes on the concave side of the curve, sometimes on the convex side, until eventually all trace of the original coil has disappeared and the bulbil takes on the appearance of a homogeneous mass of cells, more or less irregular in shape, but on the whole somewhat spherical. Not infrequently around the margin of the developing bulbil numerous free twining ends of short branches are seen in loops and coils that are more or less characteristic (figs. 37, 38). This condition is also seen in

the fruiting bodies of *Sporodesmium aurantiacum* B. and C., already mentioned. In their early development the bulbils are usually very irregular in outline, owing to the projection of secondary branches which become less prominent in the mature form.

Frequently the bulbils appear as orange or yellowish patches scattered over the surface of the culture instead of being distributed evenly. This is due to the fact that the primordia are often produced in large numbers on a single branch, as shown in figs. 35, 36. As these develop, a corresponding number of bulbils are produced, which adhere together for a considerable time, superficially



FIGS. 5, 6.—*P. nigra:* fig. 5, group of germinating bulbils; fig. 6, group of mature bulbils, showing general form and variations in size.

resembling sclerotia. As a rule, these bulbils develop very slowly, usually taking several months before they mature. Eventually, however, as the substratum becomes dried up, the individuals separate into powdery, orange colored masses. The bulbils germinate readily in nutrient fluid, several of which are shown in text fig. 4.

Papulospora nigra, n.sp. (figs. 40–47; text figs. 5, 6).—Mycelium white, procumbent, scanty, oil globules and clamp connections conspicuous; bulbils colorless at first, becoming dark brown to black, nearly spherical, 100–180 μ in diameter at maturity; primordium one or more short lateral branches which coil up and intertwine. No other means of reproduction at present known.

On old cardboard, Cambridge, Massachusetts, and on hardwood chips, Seattle, Washington.

Papulospora nigra was obtained from gross cultures of old cardboard in the cryptogamic laboratories of Harvard University, and on similar cultures of chips in the botanical laboratory of the University of Washington, Seattle. When the bulbils appeared, pure cultures were made in a manner similar to that already described. This species has been grown on a variety of media for 8 years without the perfect condition being obtained. The mycelium is white and remains so throughout the period of rapid growth. Only when the hyphae get old do they begin to change color, becoming brownish or smoke colored. The primary mycelium is procumbent and on most media is inconspicuous, but becomes more or less flocculent or cobwebby on bran or prune agar. When a culture becomes old, the whole surface is covered with black bulbils which completely obliterate the mycelium. The hyphae frequently contain many large, conspicuous oil globules (figs. 40–42). The mycelium also has quite prominent clamp connections, a condition indicating its relation to the Basidiomycetes.

The bulbils of this species resemble closely those of *P. anomala* Hotson (6) in size, form, and color. They are readily distinguished, however, by their mode of development. In the latter species the bulbils arise from "slightly swollen, colorless, intercalary cells . . . . about 4 or 5 μ in diameter, sometimes projecting considerably and resembling short stunted branches; at other times the base of a short lateral hypha swells slightly and forms the primordium." From these primordial cells branches are sent out in different directions, the lateral walls of the basal cells adhering firmly together and becoming eventually incorporated into the bulbils. It will be seen that the development of the bulbil of *P. nigra* is quite different from this. It has already been shown in the consideration of *P. aurantiaca* that the bulbils of *P. nigra* may readily be distinguished from those of *Corticium alutaceum*, and also from those of *Grandinia crustosa* by their color.

DEVELOPMENT OF BULBIL.—From the primary hyphae short lateral branches, which coil up spirally, arise, producing one or two turns (figs. 42, 43). From the cells of these spirals short branches

are developed which intertwine, sometimes incorporating the primary filament. If the lateral branch divides, as it not infrequently does, the two filaments thus formed coil up, and these with those that are subsequently produced from them intertwine (figs. 44, 45). During the early stages of development the cell walls are usually clearly distinguished, but as the bulbil grows they become more or less transparent and quite indistinct (figs. 45, 46). At the stage represented in fig. 46 the whole bulbil is colorless, the cells containing a large number of oil globules, which condition continues until almost maturity, when they begin to turn brownish. The walls gradually become more pronounced, and on account of lateral pressure they assume a more definitely angular condition. As the bulbils increase in size they become more and more spherical, so that at maturity they have a clear cut, even margin. Text fig. 6 represents a group of these bulbils. Although they vary considerably in size, the general spherical form and even outline is maintained throughout. Sometimes elongated, irregular bulbils are formed when two primordia happen to be close together and fuse as they develop. These, however, are the exceptions, and the cause of their abnormal condition can usually be detected. If the bulbils are produced rather sparingly or away from each other, they invariably become spherical.

These bulbils germinate readily in sterile water in a Van Tieghem cell or in a watch glass. Fig. 47 illustrates the germination of a bulbil, 100 μ in diameter, after 48 hours in a hanging drop. Text fig. 5 represents germinating bulbils after 3 days. It may be noticed that they are not so even in outline as in text fig. 6. The probable reason for this is that, as the hyphae are produced, the marginal cells become forced aside and disarranged, particularly when the germinating tubes come from other than cortical cells.

Papulospora magnifica, n.sp. (figs. 39, 48–69).—Mycelium white, procumbent, scanty; bulbils light brown, becoming darker with age, spherical, 37–50 μ in diameter, with one, occasionally two large central cells surrounded by a single row of cortical ones which become empty at maturity; the primordium a short lateral branch of which the terminal and occasionally also penultimate cell enlarge.

On horse dung in moist chamber cultures, New York City.

In June 1915 the writer obtained a pure culture of *Papulospora magnifica* from Dr. B. O. DODGE for identification, with permission to make a cultural study of it. The fungus was originally found in New York City in April 1912, associated with *Ascobolus magnificus* Dodge, growing on horse dung in moist chamber cultures. DODGE (3) is inclined to consider this as parasitic on the mycelium of *A. magnificus*, having traced "a direct connection between the mycelium of the parasite . . . . and the mycelium of the host." He also shows by figures this definite connection. In a later statement (4) he suggests that the *Papulospora* may be associated with *Ascobolus magnificus* "either as a parasite or as an asexual spore form of the *Ascobolus*. If the former is the case, the mycelium of the parasite is intrahyphal; if the latter is true, then the phenomenon known as 'Durchwachsung' is extremely complicated in the mycelium of this *Ascobolus*."

As has already been indicated, bulbils must in all instances be regarded as representing imperfect conditions of the higher fungi; and, like the members of other more or less clearly defined form genera, may be associated with perfect conditions included in wholly unrelated genera of the Ascomycetes and Basidiomycetes. A bulbiferous condition has been found associated with the genus *Cubonia* (6) belonging to the same family as *Ascobolus*, so that it is not inconsistent with the general characteristics of the form genus *Papulospora* to consider the bulbils of *P. magnifica* as an imperfect condition of *Ascobolus magnificus*. All efforts, however, have failed to obtain the ascocarp from pure cultures of the bulbils, although repeated attempts have been made to do so by growing the fungus on a great variety of media which were exposed to different constant temperatures. Although the majority of the species of *Papulospora* are undoubtedly saprophytic, there are some reported as parasitic. *P. parasitica* (Karsten) Hotson was described by KARSTEN (7) as parasitic on beets, while COSTANTIN (2) described *P. dahliae* as connected with the roots of dahlias, but does not state definitely that it is parasitic, although that is the general impression one obtains from his article.

In the light of the general characteristics of the genus *Papulospora* and the fact that the hyphae of *P. magnifica* have been

definitely traced for some distance inside the filaments of *Ascobolus magnificus*, we are led to the conclusion that the fungus under consideration is parasitic on the latter rather than that the bulbil is the imperfect condition of it. On all the cultures made of *P. magnifica* the mycelium grew very sparingly, being procumbent, and at times growing down into the medium, but never becoming flocculent or aerial. On potato, bran, prune, and cornmeal agar only a small amount of mycelium was produced even after several months. So meager was the development that it might easily have been overlooked unless examined carefully with a hand lens. Of the different media tried, a decoction of horse dung with agar or the horse dung itself, sterilized in an Arnold's steam sterilizer, proved the most satisfactory.

A microscopic examination frequently showed the mycelium to be a network of anastomosing hyphae (fig. 69), while at other times (figs. 65–68) enlarged food storage cells were found, the largest being 15 μ in diameter.

Development of bulbil.—The primordium of the bulbil is quite easily recognized as a short lateral branch, somewhat coiled or curved and well filled with granular material. In this development the bulbil seldom, if ever, produces a coil crosier fashion, such as does *P. parasitica*, which it most closely resembles. From the end of this coiled branch a cell is cut off, enlarges, and becomes well filled with granular food material (figs. 54, 55). This cell eventually develops into the large central cell of the bulbil. Occasionally this lateral branch twists on itself, as represented in figs. 51, 53, while at other times a secondary branch is formed from it (figs. 50, 52). The usual mode of procedure, however, is that shown in figs. 48, 49, 54, 55. It may be seen that the end cell continues to enlarge, subsequently becoming almost spherical, reaching a diameter of 10–20 μ. Before it reaches its mature size, however, several short branches, which grow over the surface, are given off from it (figs. 55–59). These branches intertwine, clinging close to the wall of the enlarged cell, finally inclosing it, so that the mature bulbil consists of a single large central cell, rich in food material, surrounded by a layer of cortical cells produced by these branches becoming compacted firmly together

laterally. In the course of development these outer cells lose their protoplasmic contents, although the walls retain more or less of the brownish color.

Although the foregoing description of the mode of development of the bulbil is the usual one, not infrequently a second large cell is formed by the primordial branch (figs. 62, 63). In such instances the further development is practically the same as where there is a single central cell. The lateral branches which eventually become the cortex are produced from both the large cells, which subsequently become completely surrounded, precisely as in the case already described.

Germination of bulbil

The bulbils of most of the species of *Papulospora* germinate with little difficulty. All of those described in this article, with the exception of *P. magnifica*, have been found to produce germ tubes quite readily. In the study of that species various media were employed in the hope that a favorable condition might be found for the germination of the bulbils. Among these were bran, potato, and prune agar, various synthetic media, as well as decoctions of horse dung used both as a liquid and associated with agar, but all these failed to produce the desired result. Finally a method that the writer had found successful in inducing the ascospores of certain species of *Ascobolus* and *Cubonia* (6) to germinate was tried with some success. Mature bulbils were put on a flamed glass slide and carefully crushed with the flat surface of a scalpel. They were then transferred to hanging drops of nutrient media, a sterile decoction of horse dung proving the best. Many of the bulbils thus crushed were totally destroyed, but in a few instances, where the pressure was just sufficient to break the cortical layer of cells without injuring the large central one, germination was produced and a branching filament soon developed (fig. 39).

The mature bulbil of *P. magnifica*, with one or two large central cells surrounded by empty cortical ones, superficially resembles certain bulbils of *P. coprophila* (Zukal) Hotson. The latter, however, consists of 1–4 (sometimes as many as 10) large central cells, only occasionally having a single central cell. Moreover, the

spiral primordium of *P. coprophila* and the flocculent and abundant mycelium differ widely from those of *P. magnifica*. The bulbils of *P. magnifica* more closely resemble those of *P. parasitica* (Karsten) Hotson than they do those of *P. coprophila*. However, in *P. parasitica*, which is described as parasitic on beets in the original description by KARSTEN, the mycelium is flocculent, the bulbils 15–21 μ in diameter, with a single large central cell invariably present, and the primordium a spiral which coils crosier fashion. Thus, the procumbent and scanty character of the mycelium of *P. magnifica*, as well as the size and mode of development of the bulbil, readily distinguish it from *P. parasitica*. In order to obtain further information regarding the relationship of these two fungi, inoculations were made in the roots of growing beets and turnips, both in the field and in the laboratory. In each case a small slice of the root was removed with a sterile knife and a cavity made in the cut surface. From a pure culture of *P. magnifica* a portion of the nutrient agar containing bulbils and mycelium was gouged out and deposited in this cavity. Over this a small piece of glass was put and the soil replaced. Although several similar experiments were carried on, no indication of a parasitic condition could be detected.

Other species that resemble the two just mentioned, such as *Physomyces heterosporus* (*Monascus heterosporus* [Harx] Schröter), *Dendryphium bulbilferum* Zukal, *Acrospeira mirabilis* Berk. and Br., etc., have already been discussed (**6**), so that it is not necessary to repeat the discussion.

Key to species of bulbiferous fungi

There are several more or less well defined characteristics that are made use of in making the following key for the members of the form genus *Papulospora*. A broad division is readily made on the presence or absence of clamp connections in the mycelium. Those forms which do not have this condition are grouped into 4 categories based on the color and size of the bulbil, namely, colorless to cream, steel gray, black, and yellowish red to dark brown. Another character used, especially in the last mentioned division, is the mode of development of the bulbils, whether from intercalary

cells, a single lateral branch, or a group of vertical hyphae. Using these characters as a fundamental basis for separation, the described species of bulbiferous fungi may be distinguished as follows:

Hyphae with clamp connections
- Bulbils dark brown to black
  - Bulbils 65–80 μ in diameter, chocolate brown ..... *Corticium alutaceum*
  - Bulbils 125–175 μ in diameter, dark brown or black; margin even
    - Primordium intercalary ..... *Papulospora anomala*
    - Primordium spiral ..... *Papulospora nigra*
- Bulbils light yellow, 52–88 μ in diameter; hyphae conspicuous, ropelike *Grandinia crustosa*
- Bulbils yellow, becoming orange, 100–250 μ in diameter; hyphae formed evenly ..... *Papulospora aurantiaca*

Hyphae without clamp connections
- Bulbils colorless, pale yellow, or cream colored
  - Bulbils cream colored, 30–35 μ in diameter; parasitic on *Geoglossum* *Papulospora candida*
  - Bulbils colorless or pale yellow, 70–100 μ in diameter, saprophytic *Papulospora pallidula*
- Bulbils steel gray, 21–36 μ in diameter ..... *Papulospora cinerea*
- Bulbils black or smoke color
  - Bulbils 75–100 μ in diameter; margin even ..... *Cubonia bulbifera*
  - Bulbils 200–300 μ in diameter; margin irregular ..... *Papulospora pannosa*
- Bulbils yellowish red to dark brown
  - Bulbils scanty; perithecia usually present
    - Perithecia with neck and lateral and terminal setae *Melanospora cervicula*
    - Perithecia with papilla and terminal setae ..... *Melanospora papillata*
  - Bulbils abundant; perithecia usually absent
    - Primordium intercalary
      - Bulbils brownish yellow; central cells 28–55 μ in diameter *Papulospora immersa*
      - Bulbils straw color; central cells 10–20 μ in diameter *Papulospora irregularis*
    - Primordium one or more lateral branches
      - Primordium normally a single lateral branch
        - Primordium spiral
          - Cells of the bulbil heterogeneous; cortex definite
            - Normally only one central cell
              - Cortex complete
                - Mycelium scanty, procumbent; bulbil 37–50 μ in diameter; occasionally two central cells *Papulospora magnifica*

Mycelium abundant, flocculent; bulbil 15–21 μ in diameter; invariably 1-celled . . . *Papulospora parasitica*
Cortex incomplete . . . *Acrospeira mirabilis*
Normally more than one central cell
Spiral in one plane; cortical cells spinulose *Papulospora spinulosa*
Spiral normally in more than one plane; not spinulose; 2–6 central cells
Bulbils dark brown . . . *Papulospora coprophila*
Bulbils brick red . . . *Papulospora rubida*
Cells of bulbil homogeneous throughout
Bulbils chocolate brown, 21–36 μ in diameter, producing *Sporotrichum* spores . . . *Papulospora sporotrichoides*
Bulbils straw color, 100–250 μ . . . *Papulospora byssina*
Primordium not spiral; bulbils large, irregular, 100–750 μ in diameter . . . *Papulospora aspergilliformis*
Primordium two or more lateral branches forming a spherical aggregation of cells at the top . . . *Papulospora polyspora*

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EXPLANATION OF PLATES XXI–XXIII

The drawings for the plates were made with the aid of a camera lucida, using different combinations of the Bausch & Lomb lenses. All the stages

in the development of bulbils were drawn with the same magnification, using 4 mm. objective and no. 12 eyepiece. The text figures are microphotographs taken by W. J. WESTERBERG. The plates have all been reduced in reproduction about three-fourths.

FIGS. 1–16.—*Papulospora pallidula.*

FIG. 1.—Hypha showing large oil globules.

FIGS. 2–6.—Dichotomously dividing primordium.

FIGS. 7, 8.—Primordia more or less irregular in their dichotomous branching.

FIG. 9.—Further development of bulbil.

FIGS. 10–12.—Second mode of forming a bulbil.

FIG. 13.—Mature bulbil germinating.

FIG. 14.—Cells of an old bulbil loosely adhering to each other; some of cells germinating.

FIGS. 15, 16.—Terminal primordia.

FIGS. 17–24.—*Papulospora byssina.*

FIGS. 17–19.—Different forms primordium may assume.

FIGS. 20–22.—Stages in development of bulbil.

FIG. 23.—Germinating bulbil.

FIG. 24.—Primordia of at least 3 bulbils from same filament at *a*, *b*, and *c* respectively.

FIGS. 25–38.—*Papulospora aurantiaca.*

FIGS. 25–32.—Variations in mode of coiling of primordium of bulbil.

FIGS. 33–38.—Other states in development of bulbil.

FIG. 39.—Germinating bulbil of *Papulospora magnificus.*

FIGS. 40–47.—*Papulospora nigra.*

FIG. 40.—Portion of hypha showing large oil globules and clamp connection.

FIG. 41.—Form of primordium that sometimes occurs.

FIGS. 42–46.—Successive stages in development of bulbil.

FIG. 47.—Mature bulbil germinating.

FIGS. 48–69.—*Papulospora magnifica.*

FIGS. 48, 54–60.—Stages in development of bulbil.

FIGS. 49–53.—Forms of primordium that occasionally appear.

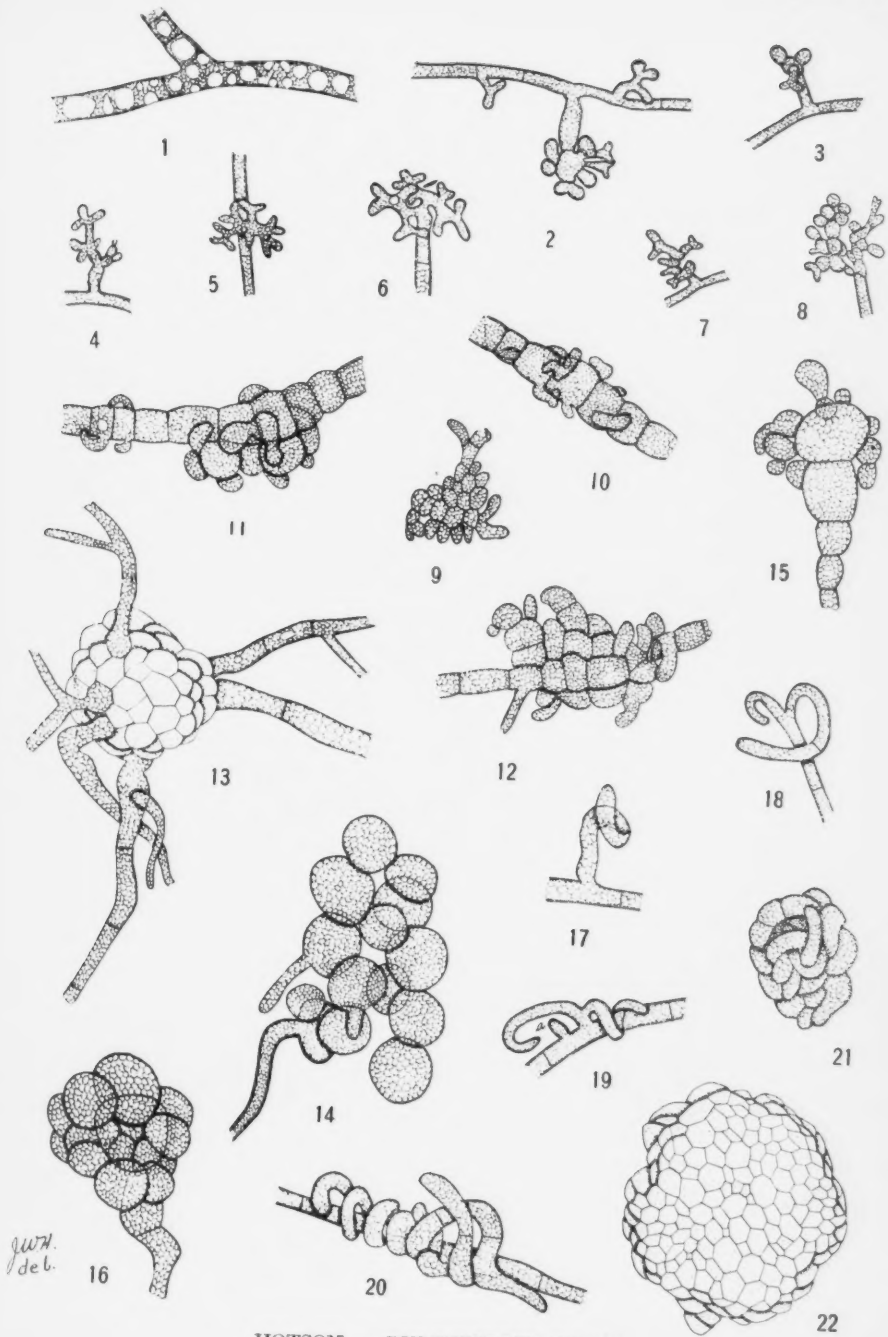
FIG. 61.—Median section of mature bulbil.

FIGS. 62, 63.—Stages in development of bulbil with 2 large central cells.

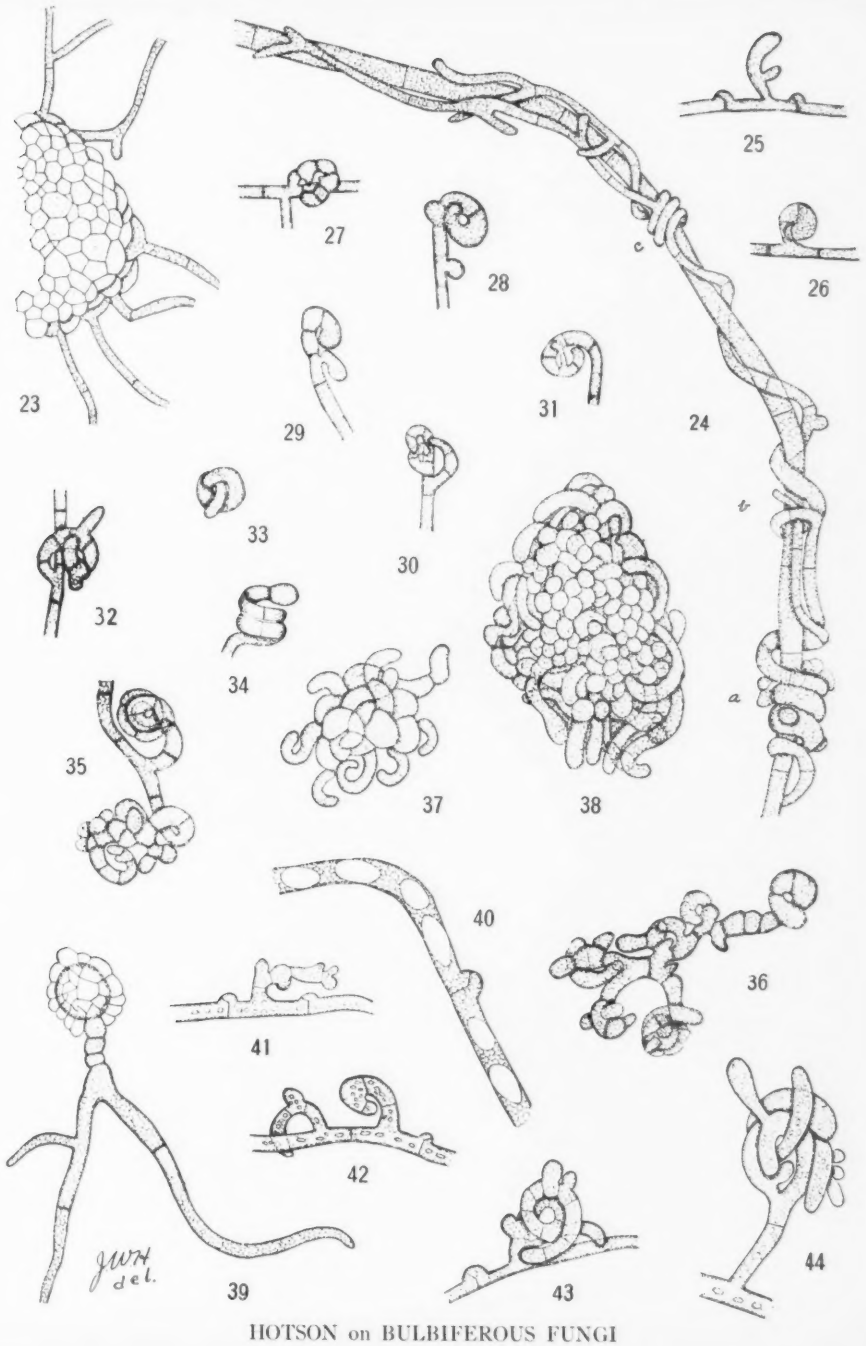
FIG. 64.—Median section of mature bulbil with 2 large central cells.

FIGS. 65–68.—Portions of hyphae with large storage cells densely filled with food material.

FIG. 69.—Portion of normal mycelium showing tendency to anastomose.



HOTSON on BULBIFEROUS FUNGI



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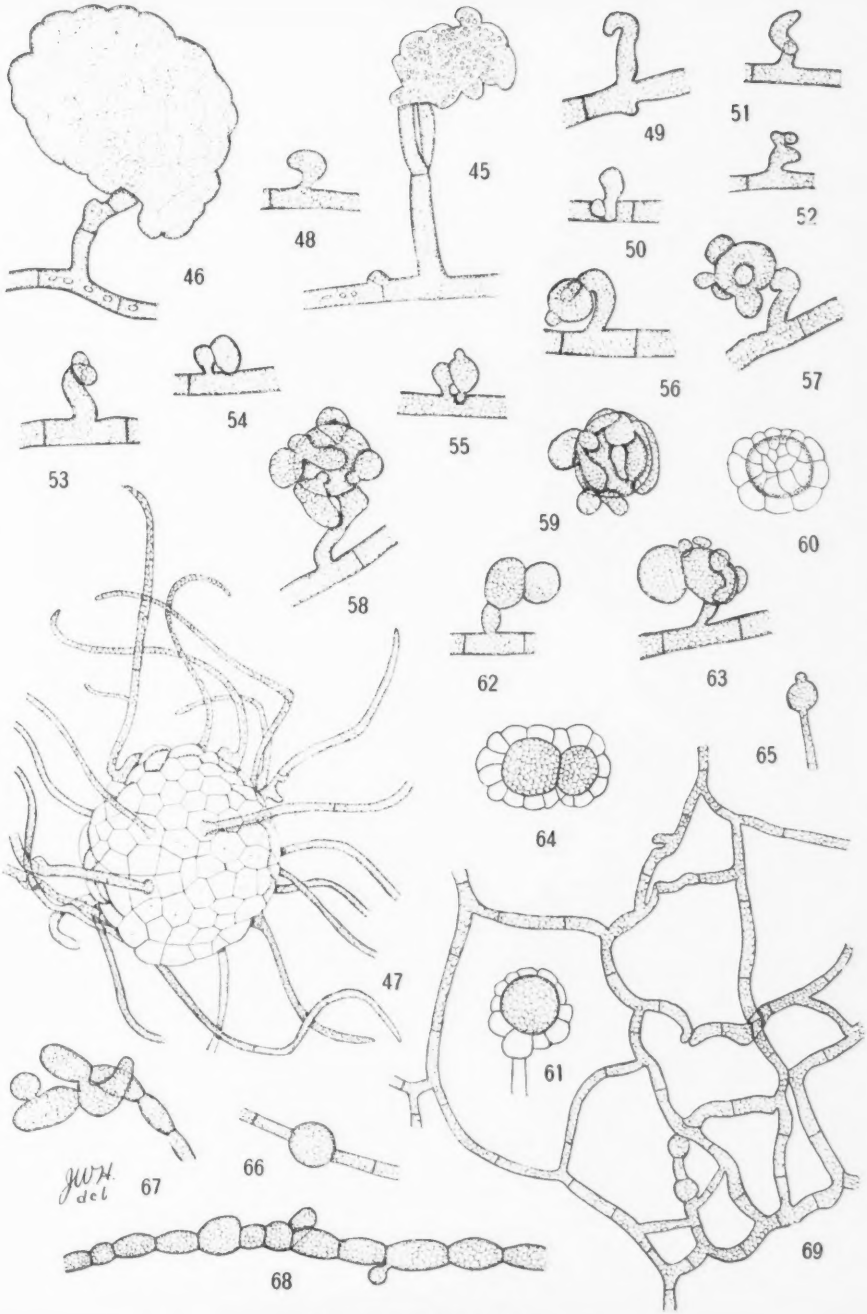

HOTSON on BULBIFEROUS FUNGI

CRYOSCOPIC DETERMINATIONS ON TISSUE FLUIDS OF PLANTS OF JAMAICAN COASTAL DESERTS[1]

J. ARTHUR HARRIS AND JOHN V. LAWRENCE

Introduction

PURPOSE OF STUDY.—In a memoir recently published[2] we have discussed in detail the reasons for considering the physico-chemical properties of vegetable saps a subject of real importance in ecology and phytogeography, and have reinforced the arguments advanced by series of determinations showing distinct differences in the osmotic pressure, or osmotic concentration, as some prefer to call it, of leaf sap from plants growing in different local habitats in the Arizona deserts. A comparison of these determinations with a series made in the more mesophytic region of the Station for Experimental Evolution[3] demonstrated a conspicuous differentiation of the Tucson and Cold Spring Harbor regions with respect to the osmotic concentration of the tissue fluids of the constituent species. In view of the conspicuous differences established between these two floras, it seemed desirable to select a forested region of as uniformly distributed and as nearly maximum rainfall as possible for comparison with the areas already studied. Thus we hoped to approximate the extreme values of osmotic concentration to be found in xerophytic and hygrophytic regions. For such a study the montane rain forest of the island of Jamaica, recently described by SHREVE,[4] seemed the most suitable locality. We therefore spent a period of several weeks during the winter and spring months

[1] Studies carried out by the Department of Botanical Research and the Department of Experimental Evolution of the Carnegie Institution of Washington, with the collaboration of the New York Botanical Garden.

[2] HARRIS, J. ARTHUR, and LAWRENCE, JOHN V., with the co-operation of GORTNER, R. A., The cryoscopic constants of expressed vegetable saps as related to local environmental conditions in the Arizona deserts. Phys. Researches **2**:1–49. 1916.

[3] HARRIS, J. ARTHUR, LAWRENCE, JOHN V., and GORTNER, R. A., On the osmotic pressure of the juices of desert plants. Science N.S. **41**:656–658. 1915.

[4] SHREVE, F., A montane rain forest. A contribution to the physiological plant geography of Jamaica. Publ. Carnegie Inst. Wash. 199. 1914.

of 1915 in a study of the osmotic concentration of the tissue fluids of the plants of the montane region. The results of this study will be published later. Fortunately, while in Jamaica we were also able to visit the remarkable coastal deserts of the southern shore. It seemed to us highly desirable to secure as large a series of determinations as possible upon the species constituting their flora for comparison with the observations already made in the Arizona deserts in the neighborhood of the Desert Laboratory. Our purpose in this paper, therefore, is to present a considerable series of novel physiological data on the plants of the desert area of the southern coast of Jamaica; to compare the flora in this regard with that of the southern Arizona deserts and of some other localities; and to hazard some suggestions concerning biological factors immediately underlying certain of the differences observed in various species of the coastal region.

CHARACTERISTICS OF DESERTS INVESTIGATED.—Lying as it does in the center of the Carribean Sea, the island of Jamaica intercepts the trade winds in a way to cause a pronounced differentiation in its climatic conditions. This is especially true on the narrow eastern end, where the Blue Mountains, attaining a height of nearly 7500 feet, separate two narrow coast plains. At Port Antonio, at sea level on the northern coast of the island, the mean annual rainfall averages more than 130 inches. At Kingston, at sea level on the southern coast of the island, precipitation is on the average less than 38 inches per year. Temperature and insolation characteristic of sea level at 18° N. latitude coupled with local peculiarities of the substratum have here resulted in a conspicuously xerophytic type of vegetation.

As limited by SHREVE[5], the desert fringes the southern coast of the island from the mouth of the Cane River, just east of Kingston, for a distance of about 70 miles to the Pedro Bluffs. Its greatest area is found in the Healthshire Hills, in the vicinity of Port Henderson, and in Portland Ridge.

As SHREVE points out, the rainfall is capable of supporting a savanna of coarse grasses and large mimosaceous trees wherever the soil is deep, as in the vicinity of Spanish Town, Porus, and May

[5] SHREVE, F., The coastal deserts of Jamaica. Plant World 13:129–134. 1910.

Pen. The desert is confined to the limestone areas which have an extremely rough surface, with layers or shallow pockets of soil which are not capable of retaining moisture or of deriving it by capillarity, and to the finely ground substratum of the coastal flats. The proximity of the sea and other factors maintain a high relative humidity. Atmometer readings by SHREVE indicate that the evaporation rates here and at Hope Gardens, which is some 6 miles inland and behind a low ridge of hills, are not very different.

All of our collections were made in the immediate vicinity of Port Henderson, a point easily accessible from Spanish Town, where it was possible to carry out the laboratory phases of the work, and which afforded access to both the rocky limestone hills and the coastal flats. Because of military restrictions, made with great courtesy, we were unable to visit all parts of the region. Probably distribution of the collections over a wider area would have modified but little the conclusions here drawn, although it might have increased the number of species upon which determinations are based.

The area considered comprises open beach, a mangrove swamp, a highly saline tract of mud flats practically free of vegetation, somewhat higher-lying flats of finely ground detrital material, and rocky limestone hills, the soil of which is relatively incapable of retaining water.

The determinations which we made on the plants of the open beach and on those of the mangrove swamp are reserved for a discussion of the sap properties of strand and mangrove swamp species, to be published later when data for other habitats (many of which have already been collected) are ready. The vegetation of the exceedingly saline mud flats is practically limited to the two well known halophytes *Batis maritima* and *Sesuvium Portulacastrum*, of which the former is much the more common, and the two mangroves *Avicennia nitida* and *Laguncularia racemosa*, which occur on the edges of the area. The determinations from this area are also omitted for the present. We restrict ourselves, therefore, to a discussion of the floras of the coastal flats and of the dry hills.

At the time of our visits, in the midwinter and early spring seasons, ephemerals were not seen. Practically all of our determinations are based upon sclerophyllous arborescent or suffrutescent

species, or upon cacti. Here, as is generally the case in desert regions, the classification of the plants with respect to growth form presents considerable difficulty. Trees are shrublike in stature and shrubs are correspondingly reduced in size. In spots where the soil is deeper or more retentive of moisture the size of the individuals may be much greater.

Describing the vegetation in terms of the species upon which we were able to secure determinations, we may note that the vegetation of the coastal flats is made up chiefly of a mesquite tree *Prosopis juliflora*, and a columnar cactus *Lemairocereus Hystrix*. Other trees or shrubs are *Caesalpinia vesicaria*, *Capparis cynophallophora*, *C. ferruginea*, and *Guaiacum officinale*. Our lists show determinations for 7 species of cacti. In addition to these, *Sesuvium Portulacastrum*, *Batis maritima*, and in places *Bromelia Pinguin* are abundant. On the rocky hillsides the more truly arborescent forms are *Bauhinia divaricata*, *Caesalpinia vesicaria*, *Canella Winterana*, *Capparis ferruginea*, *Cassia emarginata*, *Ichthyomethia Piscipula*, *Melicocca bijuga*, *Prosopis juliflora*, *Sarcomphalus Sarcomphalus*, *Schoepfia chrysophylloides*, and *Tamarindus indica*. The shrubs are *Chiococca alba*, *Croton flavens*, *Hypelate trifoliata*, *Lantana crocea* (?), *Morinda Roioc*, *Solanum bahamense*, and *Turnera ulmifolia*. The smaller ligneous species are the dwarf shrubs or half shrubs *Achyranthes halimifolia*, *Lantana reticulata*, and *Jatropha gossypifolia*, and the twiners *Echites Echites* and *Phillivertella clausa*. The only monocotyledonous plant from which a determination was secured was *Bromelia Pinguin*. The only herbaceous succulent noted was *Bryophyllum pinnatum*.

The cacti may also occur on the rocky hills, but in the immediate vicinity of Port Henderson the flora is almost exclusively of small trees and shrubs.

There are but few species in our series of determinations common to the two habitats. These are *Achyranthes halimifolia*, *Caesalpinia vesicaria*, *Capparis ferruginea*, *Jatropha gossypifolia*, and *Prosopis juliflora*.

METHODS.—The very simple technique used in making the determinations has been described in detail elsewhere.[6] Samples

[6] GORTNER, R. A., and HARRIS, J. ARTHUR, Notes on the technique of determining the depression of the freezing point. Plant World 17:49–53. 1914.

of tissue were collected in test tubes of about 100 cc. capacity and taken to the laboratory for freezing by immersion for several hours in an ice and salt mixture, in order to avoid errors in the extraction of sap as noted by DIXON and ATKINS[7] and ourselves.[8] The sap was then extracted by pressure in a small heavily tinned press bowl with a powerful hand screw. After filtering, the freezing-point lowering of the sap was determined by the use of a thermometer graduated in hundredths of degrees with divisions sufficiently large to permit reading approximately to thousandths of degrees.

In some instances a cloudiness or flocculent precipitate similar to that described by GORKE[9] was observed when the sap approached the freezing point or passed it in undercooling. We had no facilities for any investigation of these substances, but believe their pressure does not greatly, if at all, influence our results.

The measurements are recorded in degrees depression (Δ) corrected for undercooling and in atmospheres pressure (P) from a table published elsewhere.[10] The fact that a number of the determinations exceeded the range of the table as originally printed has led to the publication of a supplementary one.[11]

Presentation and analysis of data

In the following protocol the values to the extreme right opposite the species names are (whenever possible) averages. These averages are designated by bars. The individual readings upon which they are based, with their dates of collection, are entered below the species, except in the cases in which only a single determination is available and must serve, instead of an average, to represent the species.

[7] DIXON, H. H., and ATKINS, W. R. G., Osmotic pressures in plants. I. Methods of extracting sap from plant organs. Sci. Proc. Roy. Dublin Soc. N.S. **13**:422–433. 1913; also in notes from Bot. Sch. Trin. Coll. Dublin **2**:154–172. 1913.

[8] GORTNER, R. A., LAWRENCE, JOHN V., and HARRIS, J. ARTHUR, The extraction of sap from plant tissues by pressure. Biochem. Bull. **5**:139–142. *pl. 1.* 1916.

[9] GORKE, H., Über chemische Vorgänge beim Erfrieren der Pflanzen. Landwirthsch. Versuch. Stat. **65**:149–160. 1906.

[10] HARRIS, J. ARTHUR, and GORTNER, R. A., Note on the calculation of the osmotic pressure of expressed vegetable saps from the depression of the freezing point, with a table for the values of P for $\Delta = 0.001°$ to $\Delta = 2.999°$. Amer. Jour. Bot. **1**:75–78. 1914; reprinted in MATTHEW'S *Physiological Chemistry*.

[11] HARRIS, J. ARTHUR, An extension to 5.99° of tables to determine the osmotic pressure of expressed vegetable saps from the depression of the freezing point. Amer. Jour. Bot. **2**:418–419. 1915.

A. THE COASTAL FLATS

The following determinations were made on the sap extracted from the leaves of the small more or less sclerophyllous trees.

Caesalpinia vesicaria L. ..... $\bar{\Delta}=2.95$, $\bar{P}=35.4$
January 25, $\Delta=2.91$, $P=34.9$
March 26, $\Delta=3.08$, $P=37.0$
March 30, $\Delta=2.87$, $P=34.4$

Capparis cynophallophora L. (*C. jamaicensis* Jacq.) ..... $\bar{\Delta}=3.76$, $\bar{P}=45.0$
January 30, $\Delta=3.87$, $P=46.4$
April 2, $\Delta=3.64$, $P=43.6$

Capparis ferruginea L. ..... $\bar{\Delta}=4.12$, $\bar{P}=49.3$
January 25, $\Delta=4.10$, $P=49.1$
March 30, $\Delta=4.13$, $P=49.4$

Guaiacum officinale L. ..... $\bar{\Delta}=4.35$, $\bar{P}=52.1$
January 25, $\Delta=4.48$, $P=53.6$
March 26, $\Delta=4.22$, $P=50.5$

Prosopis juliflora (L.) DC. ..... $\bar{\Delta}=2.53$, $\bar{P}=30.3$
March 30, $\Delta=2.42$, $P=29.1$
April 2, $\Delta=2.63$, $P=31.5$

Three species which may be classified as dwarf shrubs or half shrubs gave

Achyranthes halimifolia Lam. ..... $\bar{\Delta}=2.86$, $\bar{P}=34.3$
January 22, $\Delta=3.23$, $P=38.7$
January 25, $\Delta=2.48$, $P=29.8$

Batis maritima L. ..... $\bar{\Delta}=4.18$, $\bar{P}=50.0$
January 22, $\Delta=4.18$, $P=50.0$
January 25, $\Delta=3.84$, $P=46.0$
March 26, $\Delta=4.58$, $P=54.8$
March 30, $\Delta=4.12$, $P=49.3$

Jatropha gossypifolia L. ..... $\bar{\Delta}=1.17$, $\bar{P}=14.1$
January 25, $\Delta=1.24$, $P=14.9$
January 30, $\Delta=1.10$, $P=13.2$

Our visit was not made during the time of the development of ephemeral plants. The only herbaceous form which we secured was the well known halophyte *Sesuvium*.

Sesuvium Portulacastrum L. ..... $\bar{\Delta}=2.86$, $\bar{P}=34.3$
January 30, $\Delta=3.28$, $P=39.3$
January 30, $\Delta=4.03$, $P=48.3$
March 26, $\Delta=4.17$, $P=49.9$
March 26, $\Delta=1.94$, $P=23.3$
March 30, $\Delta=2.11$, $P=25.4$
April 2, $\Delta=1.63$, $P=19.5$

A portion of the foregoing species are sclerophyllous and a portion are succulent-leaved plants. The tissues of the Cactaceae, which are the dominant forms on the coastal flats, yield fluids giving the following values:

Cactus Melocactus L.
January 22, for cortex, $\Delta=0.40$, $P=4.9$
for pith, $\Delta=0.49$, $P=5.9$
March 30, $\Delta=0.46$, $P=5.5$
April 2, $\Delta=0.57$, $P=6.9$
Cephalocereus Swartzii (Griseb.) Britton and Rose
March 30, for cortex, $\Delta=0.59$, $P=7.1$
for pith, $\Delta=0.70$, $P=8.5$
April 2, for cortex, $\Delta=0.59$, $P=7.1$
for pith, $\Delta=0.69$, $P=8.3$
Harrisia gracilis (Mill.) Britton
March 26, for cortex, $\Delta=0.53$, $P=6.3$
Hylocereus triangularis (Mill.) Britton and Rose
January 25, $\Delta=0.48$, $P=5.8$
Lemairocereus Hystrix (Solm Byck) Britton and Rose
for cortex, $\Delta=0.64$, $P=7.7$
for pith, $\Delta=0.75$, $P=9.0$
January 25, for cortex, $\Delta=0.44$, $P=5.2$
for pith, $\Delta=0.64$, $P=7.7$
March 26, $\Delta=0.64$, $P=7.6$
March 30, for cortex, $\Delta=0.53$, $P=6.3$
for pith, $\Delta=0.57$, $P=6.9$
April 2, for cortex, $\Delta=0.80$, $P=9.7$
for pith, $\Delta=0.76$, $P=9.1$
Opuntia Dillenii (Ker Gawl.) Haw.
January 25, $\Delta=0.57$, $P=6.8$
March 30, $\Delta=0.75$, $P=9.0$
April 2, $\Delta=0.69$, $P=8.3$
Opuntia spinosissima Mill.
January 25, $\Delta=0.57$, $P=6.8$
March 26, $\Delta=0.78$, $P=9.4$
March 30, $\Delta=0.72$, $P=8.6$
April 2, $\Delta=0.93$, $P=11.1$

The only monocotyledonous plant studied was the terrestrial *Bromelia*, which may be included here.

Bromelia Pinguin L. ..... March 26, $\Delta=0.63$, $P=7.6$

B. THE ROCKY HILLS

The classification of the plants from the rocky hills into trees, shrubs, and other growth forms has been indicated in the foregoing introductory section. Here, therefore, we merely give the results of the determinations in alphabetical order.

Achyranthes halimifolia Lam. ..... $\bar{\Delta}=2.83$, $\bar{P}=33.9$
March 26, $\Delta=3.16$, $P=37.9$
March 30, $\Delta=2.49$, $P=29.9$
Bauhinia divaricata L. ..... $\bar{\Delta}=3.04$, $\bar{P}=36.5$
January 27, $\Delta=3.10$, $P=37.2$
January 30, $\Delta=2.98$, $P=35.8$
Bromelia Pinguin L. ..... $\bar{\Delta}=0.58$, $\bar{P}=7.0$
March 30, $\Delta=0.52$, $P=6.3$
April 2, $\Delta=0.64$, $P=7.7$
Bryophyllum pinnatum (Lam.) Kurz ..... $\bar{\Delta}=0.44$, $\bar{P}=5.5$
March 26, $\Delta=0.49$, $P=5.9$
March 30, $\Delta=0.37$, $P=4.5$
April 2, $\Delta=0.50$, $P=6.0$
Caesalpinia vesicaria L. ..... January 27, $\Delta=2.26$, $P=27.2$
Canella Winterana (L.) Gaertn. ..... $\bar{\Delta}=3.18$, $\bar{P}=38.1$
January 27, $\Delta=3.29$, $P=39.5$
January 30, $\Delta=3.06$, $P=36.7$
Capparis ferruginea L. ..... $\bar{\Delta}=3.58$, $\bar{P}=42.9$
January 30, $\Delta=3.50$, $P=41.9$
March 26, $\Delta=3.66$, $P=43.8$
Cassia emarginata L. ..... $\bar{\Delta}=1.97$, $\bar{P}=23.6$
January 27, $\Delta=1.99$, $P=23.9$
January 30, $\Delta=1.94$, $P=23.3$
Chiococca alba (L.) Hitch. ..... January 25, $\Delta=3.64$, $P=43.6$
Croton flavens L. ..... January 27, $\Delta=1.47$, $P=17.7$
Echites Echites (L.) Britton (*Echites umbellata* Jacq.)
January 27, $\Delta=1.78$, $P=21.4$
Hypelate trifoliata Sw. ..... $\bar{\Delta}=2.34$, $\bar{P}=28.1$
January 30, $\Delta=2.30$, $P=27.6$
March 30, $\Delta=2.38$, $P=28.6$
Ichthyomethia Piscipula (L.) Hitch. ..... March 30, $\Delta=1.49$, $P=18.0$
Jatropha gossypifolia L. ..... January 30, $\Delta=1.02$, $P=12.3$
Lantana crocea Jacq.? ..... March 26, $\Delta=1.60$, $P=19.2$
Lantana reticulata Pers. ..... January 27, $\Delta=2.14$, $P=25.7$
Melicocca bijuga L. ..... $\bar{\Delta}=1.87$, $\bar{P}=22.4$
January 30, $\Delta=1.73$, $P=20.8$
March 30, $\Delta=1.73$, $P=20.8$
April 2, $\Delta=2.14$, $P=25.7$

Morinda Roioc L. ..... $\bar{\Delta}=1.76$, $\bar{P}=21.2$
March 26, $\Delta=1.77$, $P=21.3$
March 26, $\Delta=1.76$, $P=21.1$
March 30, $\Delta=1.84$, $P=22.1$
April 2, $\Delta=1.68$, $P=20.2$
Philibertella clausa (Jacq.) Vail. ..... January 27, $\Delta=1.51$, $P=18.2$
Prosopis juliflora (L.) D.C. ..... January 27, $\Delta=2.69$, $P=32.3$
Sarcomphalus Sarcomphalus (L.) (*Sarcomphalus laurinus* Griseb.)
January 27, $\Delta=1.63$, $P=19.6$
Schoepfia chrysophylloides (Rich.) Planch ..... $\bar{\Delta}=2.79$, $\bar{P}=33.5$
January 27, $\Delta=2.52$, $P=30.2$
January 30, $\Delta=2.66$, $P=32.0$
March 26, $\Delta=2.93$, $P=35.1$
April 2, $\Delta=3.06$, $P=36.7$
Solanum bahamense L. ..... $\bar{\Delta}=1.98$, $\bar{P}=23.8$
January 27, $\Delta=1.85$, $P=22.2$
January 30, $\Delta=1.61$, $P=19.4$
March 26, $\Delta=2.25$, $P=27.0$
March 30, $\Delta=2.12$, $P=25.4$
April 2, $\Delta=2.09$, $P=25.1$
Tamarindus indica L. ..... $\bar{\Delta}=1.75$, $\bar{P}=21.0$
January 30, $\Delta=1.76$, $P=21.2$
March 26, $\Delta=1.89$, $P=22.7$
March 30, $\Delta=1.72$, $P=20.6$
April 2, $\Delta=1.63$, $P=19.6$
Turnera ulmifolia L. ..... January 25, $\Delta=3.39$, $P=40.7$

Analysis of data

In the analysis of these data the first step is to put on one side the two species with more or less succulent leaves, *Bromelia Pinguin* and *Bryophyllum pinnatum*, and the cacti. These show low concentrations of about 6–9 atmospheres. They are not at all comparable with the other forms investigated in these deserts and elsewhere and will be discussed separately on a subsequent page.

Of the thin-leaved forms, *Jatropha gossypifolia* has a thickened, almost succulent stem. It is a form much more characteristic of the coastal flats than of the rocky hillsides. The rather tender leaves yield a sap of lower concentration than that of any other thin-leaved species.

AVERAGE CONCENTRATION IN COASTAL DESERTS.—As a preliminary to any further analysis of these data the average values for the two habitats and the different growth forms must be obtained.

For the 5 arborescent species of the coastal flats the general average is given by

Caesalpinia	$\bar{\Delta}=2.95$, $\bar{P}=35.4$
Capparis	$\bar{\Delta}=3.76$, $\bar{P}=45.0$
Capparis	$\bar{\Delta}=4.12$, $\bar{P}=49.3$
Guaiacum	$\bar{\Delta}=4.35$, $\bar{P}=52.1$
Prosopis	$\bar{\Delta}=2.53$, $\bar{P}=30.3$
General average	3.542 42.42

The 3 species of the coastal flats which have been classified as dwarf shrubs differ greatly in concentration. *Achyranthes* is a rather hard-leaved halophyte which does not penetrate to the most saline spots. It is characterized by a concentration of about 34 atmospheres as compared with about 50 atmospheres in the highly succulent *Batis maritima*, the sole species found in the more saline spots. *Sesuvium Portulacastrum* is characteristic of only the less saline portions of the flats, and shows a far lower average concentration, although some of the individual values attain about the average for *Batis*.

The actual averages are: mean depression, 2.737°; mean concentration, 32.80 atmospheres.

For the more truly arborescent species of the rocky slopes the values are:

Bauhinia	$\bar{\Delta}=3.04$, $\bar{P}=36.5$
Caesalpinia	$\bar{\Delta}=2.26$, $\bar{P}=27.2$
Canella	$\bar{\Delta}=3.18$, $\bar{P}=38.1$
Capparis	$\bar{\Delta}=3.58$, $\bar{P}=42.9$
Cassia	$\bar{\Delta}=1.97$, $\bar{P}=23.6$
Ichthyomethia	$\bar{\Delta}=1.49$, $\bar{P}=18.0$
Melicocca	$\bar{\Delta}=1.87$, $\bar{P}=22.4$
Prosopis	$\bar{\Delta}=2.69$, $\bar{P}=32.3$
Sarcomphalus	$\bar{\Delta}=1.63$, $\bar{P}=19.6$
Schoepfia	$\bar{\Delta}=2.79$, $\bar{P}=33.5$
Tamarindus	$\bar{\Delta}=1.75$, $\bar{P}=21.0$
General average	2.388 28.6

The general average for the shrubs, half shrubs, and woody twiners of the rocky slopes is given by

Achyranthes	$\bar{\Delta}=2.83$, $\bar{P}=33.9$
Chiococca	$\Delta=3.64$, $P=43.6$
Croton	$\Delta=1.47$, $P=17.7$
Echites	$\Delta=1.78$, $\bar{P}=21.4$
Hypelate	$\Delta=2.34$, $\bar{P}=28.1$
Jatropha	$\Delta=1.02$, $P=12.3$
Lantana	$\Delta=1.60$, $P=19.2$
Lantana	$\Delta=2.14$, $P=25.7$
Morinda	$\Delta=1.76$, $\bar{P}=21.2$
Philibertella	$\Delta=1.51$, $P=18.2$
Solanum	$\Delta=1.98$, $\bar{P}=23.8$
Turnera	$\Delta=3.39$, $P=40.7$
General average	2.122 25.48

Thus the concentrations determined for the smaller forms are practically as large as those for the more truly arborescent species.

Combining all the ligneous perennials of the rocky slopes (that is, omitting from the whole series of determinations only *Bromelia* and *Bryophyllum*), we have for the general average of the species means or species constants: mean depression, 2.249°; mean concentration, 27.000 atmospheres.

Combining both arborescent and suffrutescent growth forms, excepting only the herbaceous *Sesuvium Portulacastrum*, *Bromelia*, *Bryophyllum*, and the cacti, the values for the 31 species means or constants of the two habitats recognized give the following averages: mean depression, 2.505°; mean concentration, 30.05 atmospheres. By including the herbaceous perennial *Sesuvium*, the averages for 32 species means or determinations is changed to $\bar{\Delta}=2.516$, $\bar{P}=30.18$.

COMPARISON OF CONSTANTS WITH THOSE FOR MESOPHYTIC REGIONS.—The first question to be answered in the analysis of these data is that concerning the relative values of osmotic concentration in the sap of desert and mesophytic plant organisms. Specifically, do the results of this study confirm those obtained by FITTING[12] in

[12] FITTING, H., Die Wasserversorgung und die osmotischen Druckverhältnisse der Wüstenpflanzen. Zeitschr. Bot. 3:209–275. 1911.

his plasmolytic studies of the plants of North African deserts and by ourselves in our cryoscopic determinations in the Arizona desert region? With an affirmative answer to this question, a second one concerning the closeness of agreement between the two desert areas so far investigated is open to discussion.

Comparisons of the constants for sap properties here secured with those for other regions must be drawn with care and in only a preliminary fashion. This is quite obvious because of the many factors which may influence the constants, but concerning which little or no quantitative data are at present available. For example, the determinations for the Arizona deserts are based on collections made during the period of spring vegetative activity following the winter and spring rains; those for the coastal deserts were made during the dry winter season. The collections made on Long Island and in St. Louis at the Missouri Botanical Garden comprise deciduous species whose leaves must have developed during the spring of the same year. The age of the leaves of the desert plants is often quite indeterminable. Bearing these limitations in mind and remembering that there are probably many others, we note first of all that in a general way the flora of the Port Henderson deserts is in excellent agreement with that of the Tucson region in showing a high concentration of the tissue fluids of its constituent species. The exceptions only emphasize the rule.

Thus comparing the Port Henderson averages for ligneous perennials with those tentatively drawn from unpublished data for trees and shrubs for the Cold Spring Harbor region,[13] we find

Cold Spring Harbor, 14.40 atmospheres
Jamaican coastal desert
Coastal flats only, 38.81 atmospheres
Rocky slopes only, 27.00 atmospheres
Flats and rocky slopes, 30.05 atmospheres.

[13] The averages given for both the Cold Spring Harbor and the Tucson series are means of determinations, not of species means. The difference is here quite immaterial. The Cold Spring Harbor means are based on determinations made in 1914 by GORTNER, LAWRENCE, and HARRIS. They will be replaced shortly by those representing not merely determinations made in 1914 but far more extensive work by LAWRENCE and HARRIS in 1915 and subsequent work by HARRIS. The field work has been done for a summer series from the Arizona deserts, but the data cannot be completely worked up for some months.

It is idle to go further into these comparisons. It is clear that the ligneous plants of the Jamaican coastal desert, those of the rocky hills as well as of the more or less saline flats, are characterized by concentration of tissue fluids about twice as great as those of the Cold Spring Harbor region.

The extensive series of species studied by OHLWEILER[14] suffer from the disadvantage (in relation to the present paper) of being assembled from their natural habitats and grown in a Botanical Garden. All, however, are forms capable of growth in the open at St. Louis. These show a range of from about 7 to about 24 atmospheres. The average value of the 90 determinations is 14.96 atmospheres. Thus. OHLWEILER's St. Louis series agrees very closely with our own preliminary average for Long Island habitats. Here again the values are only about half as high as those determined in the coastal deserts.

COMPARISON OF CONSTANTS WITH THOSE FOR TUCSON REGION.—Turning to averages for a comparison of the concentration of the sap of the Jamaican coastal and the Arizona desert floras, the results for ligneous perennials only are: Arizona series, 24.97 atmospheres; Jamaican series, 30.05 atmospheres. Apparently concentration is somewhat greater in the Jamaican series. If the comparison between the two desert areas is to be drawn on a more analytical basis, it may be noted that the values determined for the trees of the coastal flats are of the same order of magnitude as those derived from the species of *Atriplex* examined in the Arizona salt spots. For example:

Atriplex canescens	$P=39.5$
Atriplex canescens	$P=67.5$
Atriplex canescens angustifolia	$P=32.8$
Atriplex polycarpa	$P=52.0$

In the Jamaican coastal deserts the trees and shrubs from the rocky slopes show concentrations lower than those of the coastal flats. In the Arizona deserts the plants of the rocky slopes show far lower osmotic concentrations than do those of the salt spots. Comparing Arizona and Jamaican rocky slopes the results are:

[14] OHLWEILER, W. W., The relation between the density of cell saps and the freezing point of leaves. Ann. Rept. Mo. Bot. Gard. **23**:101–131. *pl. 6.* 1912.

Port Henderson region, 27.00 atmospheres; Tucson region, 22.01 atmospheres.

With the exception of the salt spots, the bajada slopes of the Tucson region show the highest concentration. Comparing with the rocky slopes of the coastal region, the results are: Port Henderson rocky slopes, 27.00 atmospheres; Tucson region, bajada, 30.34 atmospheres.

Because of seasonal differences it is undesirable to attempt to analyze too closely the differences between the two desert areas. Such could be done if determinations upon the coastal deserts immediately subsequent to a rainy season were available. Until such data are at hand and until our determinations for the summer flora of the Arizona deserts are ready for publication, it is premature to discuss the matter further than to say that both of these regions show concentrations far higher than do those of mesophytic habitats, and that they are in good general agreement between themselves.

OSMOTIC CONCENTRATION IN THE CACTI.—From the floristic standpoint the most striking feature of these coastal deserts is the remarkable growth of arborescent cacti in immediate proximity to dense mangrove swamps. From the physiological standpoint the most remarkable result of these studies is the demonstration that the fluids of these cacti have about the same concentration as those of other desert regions.

The 28 determinations made on the sap of the 7 species belonging to the 6 genera of cacti show a range of $\Delta=0.40$ to $\Delta=0.93$, or $P=4.9$ to $P=11.1$, with an average for the series of $\bar{\Delta}=0.626$ and $\bar{P}=7.52$. Yet these cacti are growing in the same substratum as sclerophyllous arborescent species with an average concentration for the species of $\bar{\Delta}=3.54$ and $\bar{P}=42.4$. Much of the cactus-covered area has a dense undergrowth of *Batis maritima*, which has an average of $\bar{\Delta}=4.18$, $\bar{P}=50.0$. *Sesuvium*, which sometimes occurs but is not so abundant as *Batis* among the cacti, has sap averaging $\bar{\Delta}=2.60$, $\bar{P}=31.2$. Better illustrations of the diverse reaction of two organisms to the same general environmental situation could hardly be found. These results are in close agreement with the findings of those who have worked on the cacti in other regions.

As early as 1905 CAVARA[15] investigated a series of cacti by the freezing-point lowering method and gave values not very dissimilar from our own. Sap was extracted from untreated tissue. This may result in abnormally low values of the measures of osmotic concentration.

MACDOUGAL and CANNON[16] have estimated the following concentrations in atmospheres for sap of cacti at 25° C: *Carnegiea gigantea*, 6.78; *Echinocactus Wislizenii*, 5.72; *Opuntia Blakeana*, 8.88 and *O. versicolor*, 11.98.

It is interesting from the historical standpoint to note that cacti, which with certain other succulents are quite anomalous among desert plants, were perhaps the first to be considered in relation to the problem of the dependence of absorption of water by desert plants upon higher osmotic pressure of their sap. Thus LIVINGSTON[17] concluded, from determinations by the freezing-point, boiling-point, and tissue curvature methods, that the saps of *Cereus*, *Echinocactus*, and *Opuntia* "exhibit osmotic pressures no higher than those commonly found in plants of the humid regions. For these cacti at least, therefore, adaptation to desert conditions is not manifest in increased concentration of the cell sap."

From the foregoing account we may say that the cacti of the Jamaica coast exhibit sap concentration of roughly the same order of magnitude as do those of other regions. Possibly they are somewhat higher than those of purely non-saline localities, but until series in which standard methods of sap extraction have been employed are available from other habitats this cannot be asserted to be the case. Certainly the cacti, with *Bromelia* and *Bryophyllum*, are conspicuous exceptions to the general rule of high osmotic concentration in these coastal forms. To this point we shall recur later.

Results

In the foregoing paragraphs we have shown that the sap of the plant species of the Jamaican coastal deserts has an osmotic

[15] CAVARA, F., Risultati di una serie di ricerche crioscopiche sui vegetati. Cont. Biol. Veg. R. Ist. Bot. Palermo 4:41–80. 1905.

[16] MACDOUGAL, D. T., and CANNON, W. A., The conditions of parasitism in plants. Publ. Carnegie Inst. Wash. 129. 1910.

[17] LIVINGSTON, B. E., The relation of desert plants to soil moisture and evaporation. Publ. Carnegie Inst. Wash. 50. 1906.

concentration far higher than those of mesophytic regions, and quite equal to if not slightly higher than those of the winter vegetation of the Arizona deserts.

While determinations based on these species growing in other environments are as yet too few to justify detailed discussion, it seems most probable that the properties of their sap are due in part to the local conditions and not merely to the existence here of a series of species characterized by high concentration.[18]

In the few cases in which constants for a species were obtained from the coastal flats and from the rocky slopes, the values from the slopes are generally lower than those from the flats. Thus the single determination on *Caesalpinia vesicaria* from the slopes gives 27.2 atmospheres as compared with 34.4, 34.9, and 37.0 from the flats. *Capparis ferruginea* from the slopes gives 41.9 and 43.8 atmospheres as compared with 49.1 and 49.4 atmospheres when growing on the flats. *Jatropha gossypifolia* gives 12.3 atmospheres on the slopes as compared with 13.2 and 14.9 on the flats.

In the case of *Prosopis juliflora* and *Achyranthes halimifolia*, the result is uncertain. The two collections of *Achyranthes* from the slope gave 29.9 and 37.9 as compared with 29.8 and 38.7 atmospheres for the flats. *Prosopis* on the slopes yielded sap with a concentration of 32.3 atmospheres as compared with two readings of 29.1 and 31.5 from the flats.

To what extent the osmotic concentration of the sap of the sclerophyllous forms is influenced by the actual presence of salt in the leaves can only be determined by special methods. The leaves of some of the forms growing on the coastal flats, for example *Capparis ferruginea*, are perceptibly salty to the taste; others are not. It can hardly be doubted that the enormous variation in the concentration of the leaf fluids of such forms as *Batis maritima* and *Sesuvium Portulacastrum*, the leaves of which are practically reinforced water bags, is due primarily to electrolytes absorbed from the soil. The fact that the various cacti are here characterized by sap of low concentration, as when growing in true desert environ-

[18] A collection of the leaves of *Guaiacum officinale* from Spanish Town gave only $\Delta = 2.66$, $P = 31.9$ as compared with two constants each over 4° (50 atmospheres) in the coastal flats.

ments, indicates that the absorption of any considerable quantity of salts and their retention in solution is not a necessary result of existence in a saline substratum. Some physiologists have suggested that the high osmotic concentration of the fluids of desert plants is due primarily and directly to greater quantities of soluble material in the substratum than generally occurs in regions of higher rainfall. The validity of the conclusion is rendered highly improbable by the high concentrations demonstrated for the plants of the rocky hillsides.

While in general it is better to reserve hypotheses concerning the peculiarities of individual species until theoretical discussions of their relation to environmental factors can be replaced by inductions from actual quantitative data secured in the particular habitat under investigation, it may be useful to other workers, especially in the case of a problem requiring so many different kinds of specialized observation in a habitat not easily accessible to most botanists, to point out certain possible interpretations of the observed phenomena.

The question of greatest interest is that concerning the difference in behavior of the several species of the same habitat, say the coastal flats. For example, the leaves of *Prosopis* and *Caesalpinia* yield sap of a distinctly lower concentration than do those of *Guaiacum* and the two species of *Capparis*. *Jatropha gossypifolia* has sap of only about one-fourth of the concentration of that of *Batis maritima*, with which it is so generally associated. The cacti and the terrestrial bromeliad exhibit only a fraction of the freezing-point lowering shown by the hard and succulent leaves of the arborescent and suffrutescent species among which they are interspersed.

Any suggestion in interpretation of these phenomena must be purely tentative and be substantiated by, or discarded on the basis of, actual field studies. Those which are here called to the attention of ecologists are not at all speculative, but merely the result of an attempt to correlate the results of studies by a number of specialists in the various fields of desert botany.

Sesuvium Portulacastrum and *Batis maritima* are both species with highly succulent leaves. In both, the high osmotic concentration

of the leaf sap must be due primarily to electrolytes absorbed directly from the substratum. The difference between them, in so far as facts are available, seems to be an inherent physiological one. *Sesuvium* seems to be a form less tolerant of a highly concentrated soil solution than *Batis*. The local distribution of the two, therefore, is not at all comparable, and the distinctly higher concentration in the leaves of *Batis* is probably attributable to this fact.

The only suggestion which can be made concerning the anomalous position of *Prosopis* among the small trees is that it has a more deeply penetrating root system which taps underflow water, poor in solutes, derived by seepage from the neighboring limestone hills.[19] From the extensive observations in the deserts of southern Arizona it is known that the related species *Prosopis velutina* is characterized by deep root penetration. Thus SPALDING[20] and CANNON[21] both note the wide horizontal and the deep vertical distribution of the root system, which may reach a depth of 8 m. or over. CANNON[22] concludes that with uniform and penetrable substratum the species becomes a tree where the perennial ground water does not lie at a depth greater than 50 ft.

Such differences as exist between the concentration in the leaves of *Prosopis* and those of *Batis maritima* may be accounted for on the grounds of a much higher concentration of salts in the superficial soil layers.

It is interesting to note in this connection that *Prosopis juliflora* from the coastal deserts gives values of osmotic concentration in general agreement with *P. velutina* of the Arizona deserts. Thus two determinations made on young leaves in the spring of 1914[23] gave:

Santa Catalina Mountains,	$\Delta = 2.08$, $P = 25.0$
Tucson Mountains,	$\Delta = 2.33$, $P = 27.9$

[19] This suggestion was originally made by SHREVE (*loc. cit.*) to account for the presence of *Prosopis* in association with *Batis maritima* and other halophytes.

[20] SPALDING, V. M., Distribution and movements of desert plants. Publ. Carnegie Inst. Wash. 113. 1909.

[21] CANNON, W. A., The root habits of desert plants. Publ. Carnegie Inst. Wash. 131. 1911.

[22] CANNON, W. A., Some relations between root characters, ground water, and species distribution. Science, N.S. **37**:420–423. 1913.

[23] Physiol. Researches **2**:32. 1916.

Hitherto unpublished determinations made in the summer of 1916 by LEAMON and HARRIS give:

Santa Catalina bajada
Edge of arroyo, July 6, $\Delta = 2.63$, $P = 31.6$
Same tree, August 14, $\Delta = 2.40$, $P = 28.8$
Upper bajada, July 6, $\Delta = 2.87$, $P = 34.5$
Near San Xavier Mission
Mesa-like slopes, July 24, $\Delta = 2.51$, $P = 30.1$

Surely no one will venture to assert on the basis of the available data that the Jamaican *Prosopis juliflora* and the southwestern *P. velutina* are sensibly different in osmotic concentration.

With regard to the cacti, which have been shown elsewhere in this paper to have about the same concentration of tissue fluids as those found for this group growing in other habitats, the following points must be taken into account. The cacti are plants characterized by a deeply penetrating anchoring root system and a far-reaching superficially placed absorbing system. The evidences upon which this statement is based are chiefly those presented by CANNON in his large paper on the root habits of desert plants. If the coastal species agree in this regard with the forms which have been investigated, their absorbing organs are in contact with the actually dryest zone of the substratum during periods of severe drought, and with one physiologically dry, that is, characterized by a soil solution of high osmotic concentration, during periods of moderately abundant soil moisture.

Such are the conditions which result in the high concentration found in *Batis maritima*, and one might, at first thought, suppose that the cacti would also be subject to the same conditions. Two additional factors, however, are to be taken into account: (1) the cacti are organisms capable of rapid storage of water during transient periods of soil saturation,[24] and its persistent retention during

[24] The point is splendidly illustrated by two photographs of *Opuntia* published by CANNON (Amer. Nat. **40**:27–47. *figs. 2–3.* 1906). MACDOUGAL and SPALDING (The water balance of succulent plants. Publ. Carnegie Inst. Wash. 141. 1910) have dealt with the problem in greater detail. A number of other papers bearing more or less directly upon the general problem of water absorption and storage in the cacti have since appeared from the Desert Laboratory.

long periods of deprivation; (2) the rainfall in the Jamaican coastal desert region is not distributed uniformly throughout the year. During periods of heavy rainfall the salts would be highly diluted or even largely washed out of the superficial soil layers in which the absorbing roots of the cacti lie, thus permitting water intake in quantities quite sufficient to maintain the plant until conditions again become favorable for water absorption. Thus species may differ very greatly in the relationship of their sap properties to environmental factors. Two species may be rooted in the same substratum, but because of differences in root penetration or in their capacity for water absorption or retention in reality they may be living in very different environments, or reacting quite differently to the same environment.

Whether the hypotheses just advanced in explanation of the great diversity of the constants determined on the sap of particular species of plants growing in the same habitat be correct, can only be determined by intensive observational and experimental studies in the field. In the meantime they seem consistent with the available facts of desert plant physiology.

Recapitulation

In the present paper, which is one of a series on the physico-chemical properties of the tissue fluids of the plants of typical vegetations, we have presented the results of determinations of the freezing-point lowering of the tissue fluids of the plant species of the Jamaican coastal deserts; have compared the constants secured with those already available for the Arizona deserts and for mesophytic habitats; and have offered tentative suggestions concerning the proximate causes of certain of the observed peculiarities of individual species.

The deserts investigated constitute a small area on the southern coast of the island, where not merely the reduction in the rainfall due to the interception of the trade winds by relatively high mountains, but peculiarities of the substratum, contribute to the rigor of conditions limiting plant growth.

Two sub-habitats have been recognized, low-lying coastal flats of finely ground detrital material, to a considerable extent impreg-

nated with salts, and rocky limestone hills incapable of retaining moisture or of deriving it by capillarity.

The vegetation of the coastal flats comprises a number of hard-leaved trees, among which is a mesquite very similar to that of the deserts of the southwestern United States, some thin and some succulent-leaved halophytes, and a number of genera and species of cacti which form a luxuriant stand. The vegetation of the rocky hills is of a more arborescent type, consisting chiefly of dwarfed broad-leaved trees with a number of small dwarf or half shrubs which have few purely structural characteristics which would ally them to desert plants.

Taken as a whole, the species of the Jamaican coastal deserts show a concentration of their tissue fluids quite as high as, if not slightly higher than, that of as nearly as possible comparable growth forms in the Arizona deserts. The concentration of the leaf sap of the ligneous forms averages about two or three times that demonstrated in mesophytic regions.

While the plants of the rocky slopes show high concentrations, higher indeed than do those of the rocky slopes of the Arizona deserts, their constants are distinctly lower than those of the species of the coastal flats.

The sap of the cacti has only a fraction of the osmotic concentration of that of the hard or succulent leaves of the trees and half shrubs among which they are rooted. The succulent *Bryophyllum pinnatum* and the terrestrial bromeliad *Bromelia Pinguin* show far lower concentrations than do the other species. Furthermore, *Prosopis juliflora* exhibits sap concentrations distinctly lower than those of certain other of the arborescent species. These form the extreme illustration of the fact that species of the same habitat show marked differences in sap properties. Suggestions concerning the underlying causes of such differences are offered.

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A NEW METHOD OF STUDYING PERMEABILITY

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(WITH TWO FIGURES)

The writer[1] has shown the desirability of a study of permeability by some method which should be entirely independent of other methods, and yield data the interpretation of which need not depend upon any unverifiable assumptions. A method is here presented which seems to fulfil these requirements. It has proved to be exceedingly reliable; and the experiments point clearly to the errors previously made in the interpretation of the data secured by many methods, and to the validity of the conclusions based on the evidence of certain others.

Method

The method depends upon diffusion of salts or other substances through a diaphragm of living tissue. For this purpose fronds of one of the common kelps of the New England coast, *Laminaria Agardhii* (formerly identified as *L. saccharina*), proved to be extremely satisfactory material because of absence of air spaces in the tissue, ease of manipulation, resistance to adverse conditions, and especially because it was possible to secure thin sheets of tissue in which there were no wounded surfaces in contact with the solutions.

The method of experimentation was as follows. Sections of glass tubing of 18 mm. internal diameter were cut; one end of each piece was flared and the end ground flat. The resulting "cells" were either 2.5 cm. or 4 cm. in length, and were combined in pairs, each consisting of one long and one short cell (fig. 1, *A*, *B*). The unground end of the longer cell was closed by a rubber tube and pinchcock (fig. 1, *C*, *D*). Disks were cut from the fronds of *Laminaria* of such a size as nearly to cover the ground ends of the tubes.

[1] Brooks, S. C., Methods of studying the permeability of protoplasm salts. Bot. Gaz. 64:230–249. 1917.

In the experiments with living material the surface of these disks was quickly dried with filter paper, the disks (fig. 1, *E*) placed between the ground ends of a pair of cells, and the joint made tight with a stiff cement consisting of a mixture of vaseline and beeswax (fig. 1, *F*). Thus there were formed two cells separated by a diaphragm of *Laminaria* tissue. The cell supplied with the rubber tube and pinchcock (hereafter called the "lower cell") was then filled with solution and the pinchcock closed, care being taken that no air bubbles were included in the cell. The apparatus was then inverted and the upper cell filled with solution, covered to check evaporation (fig. 1, *G*), and set in a suitable support. During these operations each disk was in contact with the air less than two minutes, which was not sufficient to cause any appreciable drying-out of the tissue.

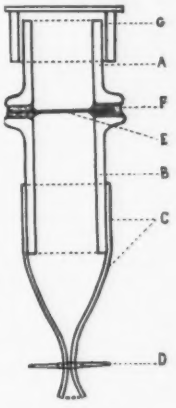

FIG. 1

In order to obtain dead tissue for experiments on the permeability of the intercellular substance, living disks were exposed, after cutting, to an atmosphere saturated with chloroform vapor at room temperature for 16–24 hours. They were next exposed to the air about one hour to allow the complete evaporation of any chloroform which remained in the tissue, and then placed in a large volume of sea water for about 24 hours to allow the establishment of equilibrium between the electrolytes of the sea water and those in the dead cells. At the end of this time the surface of the disks of tissue was dried with filter paper, and the apparatus set up as in the experiments with living material. Tissue which had died a natural death gave results in every way similar to those given by tissue killed in this manner.

The permeability of the tissue was shown by the rate of passage of salts through the diaphragm as shown by diminution of the difference of concentration between the solutions in the upper and lower cells. It is possible to measure rapidly, and with extreme accuracy, slight changes in the concentration of the solutions in either cell by determining the change in electrical conductivity. This method was therefore employed.

The solution used in the lower cells was either sea water or a pure salt solution of the same conductivity; while the upper cells contained a solution of half the concentration of that in the corresponding lower cell. Solutions of equal conductivity were used in order to facilitate comparison with the work of OSTERHOUT.[2]

Sources of error

In order to obtain accurate data, the following precautions were taken:

1. The solutions were made up with distilled water, which had a specific conductivity of about 2×10^{-6} ohms. The sodium chloride used was Baker's "analyzed"; the calcium chloride, Kahlbaum's; and the lanthanum nitrate, Eimer and Amend's "Tested Purity." For this work an error of 1 per cent in the concentration of the solutions was considered allowable.

2. In order to prevent dissolving of electrolytes from any part of the apparatus, the cells were made of Durox glass, and both cells and rubber thoroughly steamed immediately before each experiment. An apparatus of this type, set up with no *Laminaria* tissue, but with a thick layer of the vaseline-beeswax cement, and filled with distilled water, gave off only traces of electrolytes. The change in conductivity of the water in such a cell during 48 hours was equivalent to an increase of concentration of sodium chloride of less than 1×10^{-7} M. Dissolving of electrolytes from the apparatus has therefore no significance in the experiments.

3. It was necessary to eliminate the influence of temperature. As it was impracticable to conduct the experiments at constant temperature, the cells were placed outdoors, the temperature varying from $-3°$ to $+9°$ C. This amount of fluctuation produced no appreciable change in the rate at which salts passed through the tissue, and the low temperatures were exceedingly favorable to the maintenance of normal permeability.[3]

[2] Unpublished data of OSTERHOUT show that differences of osmotic pressure of the magnitude of those produced by the use of solutions of equal conductivity have little effect on the permeability of *Laminaria* during the length of time occupied by these experiments.

[3] *Laminaria* lives much longer when the temperature is low. While it may be kept alive under laboratory conditions several weeks at 0° C., it perishes rapidly at 24° C.

4. The *Laminaria* thallus is made up of masses of protoplasm (the cells) imbedded in a gelatinous intercellular substance. From this intercellular substance, in which the salts are present in the same concentration as in sea water, the salts will diffuse out into a surrounding medium, and will alter its conductivity if it be other than that of sea water. From the protoplasm, also, a similar diffusion may take place, which for convenience may be designated as "exosmosis."

That there is actual passage of salts through the tissue was shown by the fact that the conductivity of the more dilute solution always increased, while that of the more concentrated solution decreased to a corresponding degree. There was no appreciable change in the volume of either solution even during experiments whose duration was greater than 24 hours. The relative amounts of increase in the upper cell and of decrease in the lower cell, as found in the experiments, were in fair agreement with those calculated. If a given amount of salt passes from one salt solution to an equal volume of another solution having half the concentration of the first, the percentage of increase in the concentration of the latter will be double the percentage of decrease in the former. If there be a difference in volume between the two solutions, the change caused by the addition or removal of a given amount of salt will be inversely proportional to the volume. Thus, in one experiment the increase in concentration in the upper cell was 1 per cent per hour, while the decrease in the lower cell was 0.26 per cent per hour. Since the volume in the upper cell was 5.4 cc. as compared with 12.5 cc. in the lower, and the concentrations were as 1:2, the expected ratio between the changes in the two cells would be $\frac{12.5\times 2}{5.4}=4.6$; while the observed ratio was $\frac{1.0}{0.26}=3.8$.

The agreement was reasonably satisfactory, and it therefore could be assumed that changes in the concentration of the solutions in the upper cells would be nearly proportional to the amount of salt passing through the diaphragm. Two modifications of the method, however, were sufficient to eliminate entirely the errors due to both diffusion and exosmosis. The error due to diffusion of salts from the intercellular substance was eliminated by filling

the cells, when first set up, with half-strength sea water in the upper cell and sea water in the lower. Thirty minutes was ample for the establishment of a steady diffusion gradient through the tissue between the two solutions. The upper solution was then replaced by fresh half-strength sea water, after which regular readings were taken. In order to eliminate the error due to exosmosis from the protoplasm, such as might be occasioned by toxic salts, 3 controls out of each set of 11 to 13 simultaneous experiments had the more dilute solution in both cells. At the end of the experiment the average conductance of the solution in the upper cells of the controls was taken as a standard of measurement, the average conductance of all the other upper solutions being divided by this figure in order to obtain the percentage which expresses their gain as compared with the control. The figures which were obtained in this manner measure the amount of salt which has passed through the tissue, while the errors due to exosmosis from the protoplasm as well as those due to diffusion from the intercellular substance are eliminated.

5. We must eliminate the error due to variations in the thickness and maturity of the disks of tissue from different fronds, and also that due to variations in the area of tissue through which salt can pass (such as might be introduced by unavoidable smearing of the cement over the surface of the disks).[4] In order to eliminate all of these errors, controls were established in the following manner. After a preliminary half-hour with half sea water in the upper and sea water in the lower cell, the upper solution was replaced with 5.4 cc. of fresh half sea water, and the rate of change of conductivity determined at the end of 2 hours. Both upper and lower solutions were now replaced with solutions of the salt to be investigated (the fresh solutions having the same conductivity as those which they replaced), and the rate of change of conductivity determined after a further period of 2 hours. By dividing the

[4] A single experiment was conducte d to determine the influence of frond thickness. The results were entirely negative. This is in accord with the results secured by ABEL (ABEL, J. J., ROWNTREE, L. G., and LURNER, B. B., On the removal of diffusible substances from the circulating blood of living animals by dialysis. Jour. Pharm. and Exp. Ther. 5:275. 1914.), who found that diffusion of electrolytes through a collodion membrane was independent of the thickness of the membrane.

figure obtained for the salt in question by that for the control period of the same disks of tissue, we obtain a figure (given in the ratio column of table II) from which all errors due to individual variations of the disks of tissue are eliminated.

6. The method for the determination of the conductance of the solutions was as follows. The solution was poured from the cell into a U tube of such dimensions as to give a conductance of the order of magnitude most accurately determinable, namely, about 1500–2000 ohms$\times 10^{-7}$. The U tube was nearly immersed in a constantly stirred water bath whose temperature, determined to 0°.05 C., varied less than 0°.8 C. in any one set of readings. A temperature correction of 2 per cent per degree Centigrade was applied to the actual readings to reduce them to the average temperature of the set, and the results calculated from the corrected readings thus obtained. A slide wire bridge, a standard 1000-ohm bifilar resistance (supplied with current from the secondary of a Nernst string inductorium at about 300–500 oscillations per second), and a telephone as the zero instrument were used in the customary manner to measure the resistance between bright platinum electrodes immersed in the solution at the opposite ends of the U tube. The distance between the electrodes was fixed. The readings had an error less than ± 0.1 per cent. The check experiments in half-strength sea water usually gave an agreement of corrected readings within ± 0.05 per cent. It will be seen that this degree of accuracy was ample for the purpose.

Results

It is desirable first to find out how fast the various salts pass through the intercellular substance, and whether there is any selective permeability due to any source other than the protoplasm. The data presented in table I show that the cell walls intercellular substance of *Laminaria* are permeable to the salts used, and that the passage through the walls is nearly independent of the nature of the diffusing salt. In dead material the change of concentration is so rapid that owing to the decrease in the concentration gradient the rate of passage of salts through the tissue decreased, as is shown by the lower rate for the longer periods in both sea water and sodium

chloride. It is necessary, therefore, to draw our conclusions from the results of periods of equal length only. The relative permeability to different salts will then be represented by the following figures: calcium chloride 2.2, sea water 2.2, lanthanum nitrate 2.1, sodium chloride 2.1.

TABLE I

PERMEABILITY OF DEAD TISSUE OF *Laminaria*

Solution in upper cell	Solution in lower cell	Duration in hours	Change of conductivity, percentage per hour
Half sea water...	Sea water.....	5.5	1.8
$CaCl_2$, 0.14 M...	$CaCl_2$, 0.28 M..	4.5	2.2
Half sea water...	Sea water.....	12	1.3
" " " ...	" "	5.5	2.2
NaCl, 0.26 M...	NaCl, 0.52 M ..	5	2.0
Half sea water...	Sea water.....	12	1.2
La_2Cl_6, 0.05 M..	La_2Cl_6, 0.10 M..	4.5	2.1
NaCl, 0.26 M...	NaCl, 0.52 M ..	4.5	2.1

It appears probable that the slightly lower rate of diffusion of sodium chloride may have been due to a slight irreversible decrease in the permeability of the intercellular substance caused by the lanthanum nitrate, by which the tissue had been bathed immediately previous to the experiment with sodium chloride. This would be in accord with unpublished data secured by OSTERHOUT by determination of the conductivity of the tissue.

The differences which might be expected to arise as an expression of the diffusion coefficients of the salts are evidently of so small an order as to fail to influence appreciably the rate of diffusion through dead tissue. In view of the very imperfect state of our knowledge of diffusion coefficients, it would be unprofitable at the present time to attempt any further explanation of the influence of that factor in our experiments.

It will be seen from the data given in table II that the presence of living protoplasm greatly decreases the permeability of the tissue as a whole. Living protoplasm offers, therefore, a very considerable resistance to the passage of salts. That it is not normally (in sea water) impermeable to salts will appear from the following considerations. The permeability of the protoplasm for conven-

ience may be considered as the amount of salt passing through the tissue, expressed as the percentage of the amount passing through tissue bathed by sea water, as shown in the ratio column of table II. If the protoplasm be assumed to be wholly impermeable to salts of lanthanum, the figure 0.45, expressing the permeability of the tissue as a whole, would in this case represent diffusion through the intercellular substance only. Since this part of the tissue has been shown (cf. table I) to have no appreciable selective permeability, we may assume that not more than 0.45 of the permeability of the tissues to sea water, which is 1.07, is due to passage of salts

TABLE II

PERMEABILITY OF LIVING *Laminaria*

Experiment number	First period				Second period				Ratio
	Upper solution	Lower solution	Duration h. m.	Change of conductivity, percentage per hour	Upper solution	Lower solution	Duration h. m.	Change of conductivity, percentage per hour	Second period / First period
18..	Half sea water	Sea water	2:05	0.73	Half sea water	Sea water	2:00	0.78	1.07
19..	"	"	2:00	0.79	NaCl, 0.26 M	NaCl, 0.52 M	2:00	1.11	1.41
22..	"	"	2:06	0.73	$CaCl_2$, 0.14 M	$CaCl_2$, 0.28 M	2:02	0.51	0.70
17*a*.	"	"	1:35	0.73	$La_2(NO_3)_6$, 0.05 M	$La_2(NO_3)_6$, 0.10 M	1:35	0.33	0.45

through the intercellular substance. There remains $1.07 - 0.45 = 0.62$, which represents that part of the salt which passes through the protoplasm. In sea water, therefore, a minimum of $\frac{0.62}{1.07}$, or 58 per cent of the salt, passes through the protoplasm, but the exact significance of this figure is doubtful owing to the arrangement of the protoplasmic masses in the tissue.

In order to show the order of magnitude of the total diffusion through the living tissue, the results may be expressed in terms of the amount of salt in gm. molecules passing through 1 sq. cm. of tissue per hour. Ignoring the exceedingly slight change in molecular conductivity induced by such small changes of concentration,

the conductivity will be proportional to the concentration, and a change of 1 per cent in the conductivity of a 0.26 M solution may be assumed to indicate an increase of 0.0026 M in the concentration. An increase of this size in 5.4 cc. of solution will necessitate the addition of $\frac{5.4}{1000} \times 0.0026$, or 0.0000140 gm. molecules of salt. If we divide the figures obtained in this manner for the various salts, by the area of tissue in sq. cm. through which salts can pass, we obtain the figures given in table III. The figure for sea water was obtained by assuming all of its conductivity to be due to sodium chloride; but since sea water contains about 12 per cent of its electrolyte as salts of bivalent elements, which have a higher molecular conductivity than sodium salts, its actual molecular content is less than that of a sodium chloride solution having the same conductivity, and the figure given in table III is thus slightly too high.

TABLE III

GRAM MOLS DIFFUSING PER SQ. CM. PER HOUR THROUGH LIVING *Laminaria*

Upper solution	Lower solution	Gm. mols diffusion
Half sea water.....	Sea water.....	0.0000425
NaCl, 0.26 M.....	NaCl, 0.52 M.....	0.0000610
$CaCl_2$, 0.14 M.....	$CaCl_2$, 0.28 M.....	0.0000150
$La_2(NO_3)_6$, 0.05 M..	$La_2(NO_3)_6$, 0.10 M...	0.0000034

The data of tables II and III also show that there is a selective permeability to the salts used. Sodium chloride is allowed to pass through the tissue most rapidly, the salts of sea water next, calcium chloride considerably less rapidly than sea water, and lanthanum nitrate least of all. That the effect is produced in large part by the kations, as was to be expected, is shown by the fact that preliminary experiments with lanthanum chloride (lacking the preliminary comparison period in sea water) showed a permeability comparable with that to lanthanum nitrate. Thus in one experiment with lanthanum chloride the change of conductivity of the upper solution was 0.30 per cent per hour, while that quoted for lanthanum nitrate is 0.33 per cent per hour. Whether

protoplasm is at all permeable to lanthanum salts cannot be decided with the data furnished by these experiments.

It might be supposed that the protoplasm was normally more permeable to sodium chloride than to the other salts of sea water, and that therefore when bathed by pure sodium chloride solution more salt would pass through the diaphragm. On the assumption that the tissue is permeable only to the sodium and potassium chlorides, the molecules of which constitute 88 per cent of the molecules of salt in sea water, the rise in permeability on substitution of sodium chloride solutions for sea water would be only that from 88 to 100. The observed rise is much greater, namely, from 76 to 100, and in addition it must be remembered that the calcium and magnesium salts of sea water are probably able to penetrate the tissue to some extent. Sodium chloride must increase the permeability of the tissue therefore.

By analogy, it might be assumed that the permeability of the protoplasm decreased under the influence of calcium and lanthanum salts. In order to obtain more exact information in respect to this question, a set of experiments was conducted in which the permeability was determined during successive periods of treatment with a given salt. The solutions in both the upper and lower cells were renewed at the beginning of each period. The results are shown in table IV and fig. 2.

From these experiments it will be seen that the increase of permeability due to sodium chloride is progressive, and that it leads in the course of about 4 hours to a permeability of the tissues corresponding to that of dead material. The effect of calcium chloride, on the other hand, is to cause a temporary decrease in permeability, followed by a rise which at the end of about 12 hours leads to a permeability comparable with that for dead material. At the end of this time the material had assumed the green color characteristic of dead material.

The experiment with sea water was conducted under conditions extremely unfavorable to the maintenance of normal permeability, the temperature rising to 14° C. during the third and fourth periods. Partial recovery is shown in the succeeding periods during which the temperature decreased. The last period was begun about 24

hours after the beginning of the experiment, and shows that the tissue, which had only partially recovered its normal permeability,

TABLE IV

PROGRESSIVE CHANGES IN PERMEABILITY OF TISSUE OF LIVING *Laminaria;* EXPRESSED AS RATE OF CHANGE OF CONDUCTIVITY OF SOLUTION IN UPPER CELL, IN PERCENTAGE PER HOUR

UPPER SOLUTION, HALF SEA WATER; LOWER SOLUTION, SEA WATER			UPPER SOLUTION, $NaCl$, 0.26 M; LOWER SOLUTION, $NaCl$, 0.52 M			UPPER SOLUTION, $CaCl_2$, 0.14 M; LOWER SOLUTION, $CaCl_2$, 0.28 M		
Period begun at	Duration in min.	Rate of change	Period begun at	Duration in min.	Rate of change	Period begun at	Duration in min.	Rate of change
6:45 A.M..	120	0.67	2:40 P.M....	120	1.11	9:33 A.M....	122	0.51
9:15 A.M..	124	0.78	5:10 P.M	150	2.30	12:05 P.M....	124	0.82
11:45 A.M..	121	1.01	8:15 P.M....	130	2.50	2:45 P.M....	121	0.69
2:20 P.M..	132	1.27	.....	.....	.....	5:25 P.M....	120	1.37
5:00 P.M..	170	0.81	.....	.....	.....	8:10 P.M....	135	2.05
8:20 P.M..	139	0.97	.....	.....	.....	.....	.....	.....
6:05 A.M..	120	0.96	.....	.....	.....	.....	.....	.....

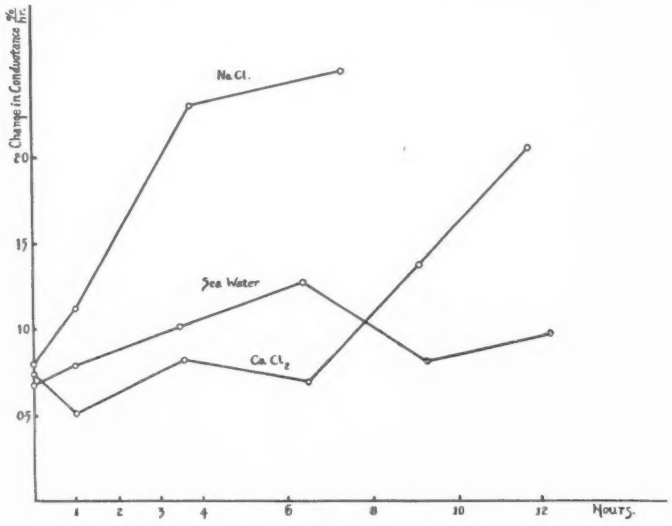

FIG. 2

suffered no further injury during the period of low temperature (0–4° C.) intervening between the fifteenth and twenty-fourth

hours. The disks were still brown and apparently uninjured even after 48 hours in the apparatus. Certain experiments with lanthanum salts indicated that the effect of lanthanum would resemble that of calcium, differing chiefly in that the alterations of permeability would take place more rapidly.

Summary

1. The protoplasm of *Laminaria* is normally permeable to the salts of sea water.

2. Sodium salts cause an increase of permeability which culminates in death.

3. Calcium and lanthanum salts cause a decrease in permeability, followed by an increase which culminates in death.

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EVAPORATION RECORDS FROM THE GULF COAST

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(WITH FOUR FIGURES)

In connection with field work in northern Florida, undertaken to determine the composition and limits of certain gulf coast forest associations and their relations in succession, and following the instructions of LIVINGSTON,[1] FULLER,[2] and the work of others in the north and west, records of the daily rate of evaporation in several of the typical plant associations were kept, some of them running through a period of 19 successive months. The Livingston rain-correcting atmometers were used and care was taken to follow the directions for their operation in all particulars. It was planned to visit each station once in two weeks, and this was carried out with few interruptions.

Station no. 1 was in an upland hammock forest on Norfolk Fine Sandy Loam. *Magnolia grandiflora*, *Fagus grandifolia caroliniana*, and *Acer floridanum* Pax (or *Acer saccharum floridanum* Sarg. Silva N. Am.) were the chief trees, with an undisturbed growth of young trees of these and other species and of mesophytic shrubs and herbs. The apparatus at this station suffered various mishaps, and the record is broken, but from January to May 1913, which includes the times of extreme minimum to maximum evaporation for all the stations (except that of *Pinus palustris*), the record is complete.

Station no. 2 was in an upland oak forest on Orangeburg Fine Sandy Loam, 2.5 miles west of Tallahassee. In this forest nine-tenths of the trees were deciduous, with *Quercus falcata*, *Q. stellata*, and *Carya alba* predominating. *Cornus florida* was common, but *Q. virginiana* and *Ilex opaca* (broad-leaved evergreens) were rare. *Myrica cerifera*, *Rhus copallina*, *Ilex vomitoria*, *Ceanothus americanus*, *Aralia spinosa*, *Vaccinium stamineum*, *Callicarpa americana*,

[1] LIVINGSTON, B. E., Evaporation and plant habitats. Plant World **11**:1–9. 1908; Operation of the porous cup atmometer. Plant World **13**:111–119. 1910.

[2] FULLER, G. D., Evaporation and plant succession. BOT. GAZ. **52**:193–208. 1911.

and *Viburnum rufidulum* were the principal shrubs about the station and made a rather close shrubbery throughout the woods. The list of herbs shows nothing especially distinctive in the way of species, as they are practically the same as those of the beech and short-leaved pine forests in which stations 3 and 4 were located.

Station no. 3 was in an upland short-leaved pine forest about 1 mile north of Tallahassee, on Orangeburg Sand. The mature trees were almost entirely *Pinus echinata*, but this wood was well advanced in the undergrowth toward the oak-hickory stage; the young half-grown trees of *Quercus falcata*, *Q. stellata*, and *Carya alba*, and also of *Q. virginiana* and some *Fagus grandifolia caroliniana*, made one story, under which was a lower growth of *Quercus nigra*, *Q. laurifolia*, *Q. marilandica*, *Crataegus* spp., *Prunus angustifolia*, *Cornus florida*, *Nyssa sylvatica*, *Vaccinium arboreum*, *Callicarpa americana*, and *Viburnum rufidulum*, with numerous lianas as *Smilax glauca*, *S. pseudo-china*, *Cissus* spp., *Vitis rotundifolia*, *Gelsemium sempervirens*, and *Lonicera sempervirens*. Common herbs of the station vicinity were *Arisaema Dracontium*, *Oenothera biennis*, *Sanicula canadensis*, *Gerardia purpurea*, *Mitchella repens*, *Eupatorium album*, and *Chrysopsis mariana*.

Stations 2 and 3 were operated for 19 months continuously without a break or mishap.

Station no. 4 was in a beech wood about one-fourth of a mile east of the station in the pine forest. To the west and south of this forest was a short-leaved pine wood in a still later stage than the one in which station 3 was placed. The proportion of deciduous trees was larger and the trees older, while the undergrowth was much less dense, which may largely be accounted for by the fact that this wood had been stocked with hogs and cattle for some years. To the north its character changed quite abruptly, the pines being few and the number of mature deciduous trees not large, but the undergrowth was very dense. Throughout this wood (an area of some 40 acres) were scattered beeches of all ages. Magnolias were less common. The beech opening in which the station was located apparently had once been somewhat swampy, although but little lower than the rest of the ground and scarcely wetter except after heavy rainfalls. As a whole the forest was level and formed part of

a level hilltop. The soil was mainly Orangeburg Sand, which is a transitional type between the Orangeburg and Norfolk Fine Sandy Loams, and which, as stated in the soil survey, is occasionally found in small isolated patches within the Orangeburg Loam areas, occupying slight elevations which have not suffered from erosion.

The evaporimeter was placed in the portion of the woods freest from shrubs or undergrowth of any kind, there being comparatively few herbs in the vicinity, those noted being mainly the same as those of the open pine wood, except that the fireweed (*Erechtites hieracifolia*) was common. This station suffered several interruptions during the 18 months of its operation, owing to the pasturing animals and other causes.

The four stations described were all on the hills or elevations over 100 ft. above sea level, and none of them suffered from frost.

Station no. 5 was established in September 1912, about 5 miles southwest of Tallahassee, on low sandhill soil, a strip of gently rolling yellowish sand, covered with a dense growth of scrub oaks, only an insignificant part being under cultivation. It has doubtless been a shoal, extending east and west parallel with the edges of the abrupt upland to the north which once formed the shore line. This sandhill area is characterized everywhere by a very definite as well as limited tree flora. There are 3 scrub oaks and 2 pines, the latter being scattered. *Quercus catesbaea*, *Q. margaretta*, *Q. cinerea*, and the long-leaved pines, *Pinus palustris* and *P. caribaea*, are the species. The chief undershrubs near the station were *Asimina pygmaea*, *Vaccinium arboreum*, and *V. corymbosum*. *Ascyrum hypericoides* was also noted at this station and appears to be generally ubiquitous, although frequent rather than abundant. The herbs were *Asclepias tuberosa*, *Scutellaria integrifolia*, *Gerardia purpurea*, *Eupatorium aromaticum*, and *Liatris laevigatus*. Although the sandhill region is very sparsely inhabited, the records from this station happened to be frequently interrupted by meddlesome hunters as well as by fire, frost, and a cyclone. In the effort to keep the apparatus hidden it was twice moved. The cup was broken by frost on November 28, 1913.

Station no. 6 was in a long-leaved pine forest on Norfolk Sand, 4 miles southwest of Tallahassee and a quarter of a mile north of

station no 4. At this station the evaporimeter was broken by frost once in the second winter of its history, on January 11; it was shot to pieces once; and was once in the immediate path of a June cyclone which blew down most of the trees in a track 800 ft. wide. By this storm the cup was demolished but the reservoir was unbroken. The location was then changed a few rods to the east. This station was peculiar in that the trees were essentially like those of the Leon Sand station (no. 7) near Lake Jackson, and the herbaceous plants like those on the sandhill soil. At the outer border of this soil, where the Norfolk Sand and the sandhill join, the scrub oaks gave way abruptly, the line between the two soils being generally as sharp as if the planting had been artificial.

The Leon Sand station, no. 7, was in operation more or less continuously for 18 months, being broken by frost once the first winter and twice during the second winter; it was also once in the path of a fire. This Leon Sand is situated 9 miles northwest of Tallahassee, being a strip of long-leaved pine forest about 200 yards wide. This small area is bordered on the north by a slough which is directly bordered by Norfolk Sand, and to the south the soil is the Norfolk Fine Sand, each with characteristic vegetation. This strip of the Leon Sand is an outlying neck of a larger area of the same soil 2.5 miles wide and 1 mile long, the only area of this particular soil in the northern part of the county which is accessible to the railroad. However, in its growth it is typical of the larger area of the flatwoods to the southeast. This soil, wherever it occurs, is very level and poorly drained and therefore excessively wet a large part of the year. Station no. 7, therefore, was on the wettest soil of any, and its vegetation should be compared with that of station no. 6, which also supported a long-leaved pine forest on the Norfolk Sand, one of the driest soils of the region. The wood on the Leon Sand was very open and the destruction caused by turpentining had still further thinned it. Owing partly to frequent fires and partly to the general quality of the soil and the drainage, the undershrubs were very low, seldom exceeding 2 ft. in height. The forest floor was sparsely covered with wire grasses. Apart from the pines, the trees noted about this station were occasional small specimens of deciduous trees, as *Quercus falcata*, *Q. virginiana*, *Q.*

nigra, *Liquidamber styraciflua*, *Acer rubrum tridens*, and *Nyssa sylvatica biflora*. The undershrubs were *Quercus myrtifolia*, *Q. minima*, *Pyrus arbutifolia*, *Rubus villosus*, *Rhus copallina*, *Ilex glabra*, *I. lucida*, *Hypericum fasciculatum*, *Vaccinium virgatum tenellum*, *Viburnum nudum*, and *V. molle*. A common liana was *Gelsemium sempervirens*, but the most common plant of all was *Serenoa serrulata* (saw palmetto). The herbs about this station make a distinctive list, the majority being species of Compositae, as *Helianthus angustifolius*, *Rudbeckia laciniata*, *Aster Tradescanti*, *Solidago fistulosa*, and *Bidens bipinnata;* there were also *Polygala lutea*, *Viola lanceolata*, *Sabatia gracilis*, *S. lanceolata*, *Pinguicula lutea*, and *Valerianella radiata*.

Stations no. 8 and no. 9 were located in October 1913 in the meadow of the Ocklocknee River. One was placed in a willow growth on the south bank, the apparatus being located in the outer border of the narrow strip of trees edging the stream and 5 or 6 ft. above the water at its normal stages. At this point a strip of bare sand, 15–20 ft. wide, separated the willows from a birch zone. Immediately bordering the river this meadow strip was about one-fifth of a mile wide, bounded on the east by a strip of Norfolk Sand with the long-leaved pines. The area occupied by the willows was subject to frequent overflow and no other plants seemed able to maintain themselves permanently in this zone. The growth here was not luxuriant, few of the trees exceeding a height of 10 or 12 ft. The records from these stations were interrupted by frost about December 21, 1913, and again on January 18, 1914, while from February 1 to March 28 the apparatus was covered by water two-thirds of the time and no records were secured. The birch station, 4 ft. higher and 15–20 ft. farther inland than the willow station, suffered similar interruption, except that the interval due to the flood was two weeks shorter and the apparatus was reestablished March 15, at which time the willow station was still completely under water. On the whole, the growth here was more luxuriant, although few of the trees had trunk diameters greater than 6 inches, or height greater than 15–20 ft.

Laboratory examination of each of the soils at the several stations was made to determine the organic content and general

character. The Orangeburg Fine Sandy Loam soil from the Spanish oak-post oak station, when dried, was a dark brownish gray. It is an excellent soil, rich in humus, and the drainage in the locality of the station was good. The soil from the short-leaved pine station was a medium brownish gray, similar to the preceding but containing a larger proportion of sand (Orangeburg Sand), and less humus. The soil from the beech wood was the same according to the classification of the United States Soil Survey Report, and it resembled that of the pine wood in the samples taken in the course of this study, but both soil and subsoil were of a brighter reddish tinge. The area of the beech station was hardly so well drained as that of the pine wood. The soil from the *Pinus palustris* forest on Norfolk Sand was very similar in color (both soil and subsoil) to that of the short-leaved pine, but contained decidedly less clay, separating in loose grains when dry, while the other dried in small lumps. It was also less rich in humus. The drainage was excellent to excessive. The soil from the scrub oak forest (which adjoined the preceding on the south) was very similar to Norfolk Sand in texture but a brighter red and perceptibly poorer in humus. The soil from the Leon Sand station was a medium gray sand with a very small admixture of organic materials. It was too wet for agricultural crops.

The evaporation records from the mesophytic forest (station no. 1), during the time it was steadily running, showed a consistently lower average and actual rate than any other station. The minimum monthly rate for this station was 6.05 cc. per day in January. The actual minimum was 4.5 cc. in January. The maximum monthly rate was 10.27 cc. daily in April, and the actual maximum was 11.9 cc. the first of May. The mean average rate for the 4 months covering the time from the minimum to the maximum was 8.5 cc. per day, an interesting result in comparison with the record of evaporation for beech-maple forests in the north.

Station no. 2, the Spanish oak-post oak forest, in comparison, gave a record of 9.90 cc. per day for the same period of the same year. The average of this station for 18 months' continuous and unbroken record, however, is 14 cc. daily. The minimum monthly

average is 9.94 cc. per day in December, and the maximum monthly average is 22.20 cc. daily in April. The actual minimum during the 18 months was 7.01 cc. in October, and the actual maximum was 29.28 cc. in March.

The short-leaved pine station, no. 3, averaged 11.67 cc. per day for the same period of the same year as given for stations nos. 1 and 2; and for an 18 months' unbroken record, 14.22 cc. per day. The minimum monthly average was 8.83 cc. per day in January, and the maximum monthly rate 19.7 cc. daily in April. The actual minimum was 5.18 cc. in January, and the actual maximum was 25.04 cc. in May. Comparison of stations 2 and 3 thus shows the averages as based on the yearly rate to be very similar. If, however, a comparison be made of their rates during the two general periods for deciduous trees, namely, with full foliage and without full foliage, or summer and winter (from June to November, and from November to June), the comparison shows that the June to November season gave a rate of 12.49 cc. daily for the oak forest, and of 13.8 cc. daily for the pine forest; while the winter rates (November to June) were, respectively, 15.69 cc. and 13.70 cc. This demonstrates a greater evaporation in winter in the deciduous forest, and the greater evaporation in summer from the pine forest. However, the similarity in the yearly rate, covering as it does the extremes of the two years, shows that the evaporation in the two forests was not greatly different, and this may seem related to the fact that at both stations there was an abundance of shrubbery of similar composition; if anything, that of the pine wood, being in two stories, was the thicker, and the telescoping of these two associations was conspicuous.

The beech forest, which had been burned and pastured, gave an average result of 16.63 cc. daily for the whole period of 18 months (with one break in the record for November to December 1912), an average of 11.21 cc. per day for the period from January 1 to May 1, 1913, and an average of 13.4 cc. for the summer (full foliage) period. This last compares with the same average of the pine wood, showing a similarity between the pine forest and the pastured beech wood. June shows the minimum monthly rate for this forest, and March the maximum (fig. 1).

Station no. 5, that of the scrub oaks, gave 15.52 cc. daily for 18 months, and 15.30 cc. daily for the period from January to May 1913. For the summer (June to November) the average was 13.95 cc. daily, corresponding to the short-leaved pine and the pastured beech wood. The winter rate was 14.1 cc., intermediate between that of the oaks and pine. The period of greatest evaporation was April; while December, January, and February showed

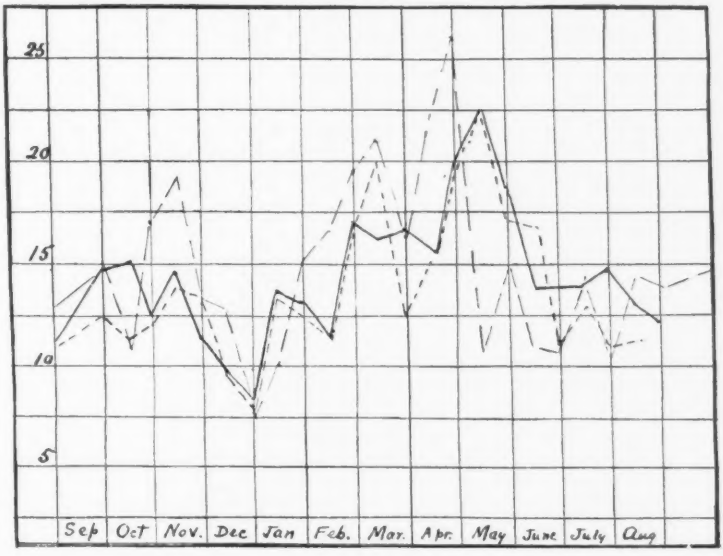

FIG. 1.—Chart showing comparison of yearly range of evaporation in Spanish oak-post oak forest (dotted line); short-leaved pine forest (heavy line); grazed beech forest (broken line).

about the same minimum. The actual minimum was 7.39 cc. in late December, and the actual maximum 27.97 cc. in early May. This forest, therefore, does not show such wide variation for the seasons as do the others given, and the curve representing the years' averages runs more evenly for this forest than does that of any other except the flatwoods. This evenness may be related to the fact that, although the trees are deciduous, their leaves, after dying and turning brown, remain on the branches most of

the winter; and as they are coriaceous in texture and more or less coated with felt on the under surface, they remain intact until the time for the new foliage. The low summer rate (as compared, for example, with the long-leaved pine rate) also may have a relation to the fact that although there is an absence of shrubs or undergrowth of importance, these trees are dwarfed or scrub-like, and the foliage grows low on the trunks; when growing closely they make a thicket-like forest.

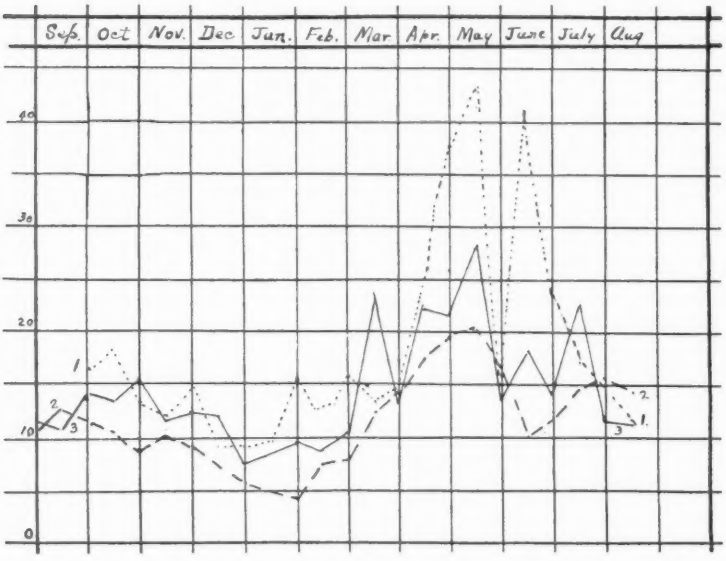

FIG. 2.—Chart showing comparison of average yearly rates of evaporation in scrub oak forest (heavy line); flatwoods (broken line); long-leaved pines on dry land (dotted line).

Station no. 6, in the dry pine wood, gave the average evaporation per day of 17.9 cc.; 12.28 cc. for the period January to May; 18.25 cc. for the summer period; 19.2 cc. for the winter period; with minimum monthly average of 8.9 cc. in December and a maximum of 32.5 cc. in April. The actual minimum was 4.15 cc. and the maximum 56.19 cc., showing the widest range of any station (fig. 2).

The flatwoods station, on Leon Sand, gave an average for 18 months (with a break in the record for December and January 1912–1913) of 12.99 cc. per day. The January to April average for 1913 is not complete, but for the summer and winter periods the averages are, in order, 13.24 cc. and 11.17 cc. The minimum month is January, 5.94 cc. per day; the maximum in May is 19.8 cc. per day. The actual minimum falls lower than that of any other, being 3.88 cc. in February, and the maximum was 25.44 cc. in May.

The meadow stations were not in operation for a long enough time to give results covering a year. From October to June the willows averaged 12.47 cc. daily, comparable to the flatwoods station. The average for the birch station for the time was 13.98 cc. daily. Their minima occurred in January and maxima in May.

Arranging the stations in the order of their yearly averages of evaporation, beginning with that having least evaporation, their order is as follows: hammock climax forest, willow (meadow) zone, flatwoods, birch (meadow) zone, Spanish oak-post oak forest, short-leaved pine forest, scrub oak forest, beech wood (open and grazed), long-leaved pine forest. Omitting the meadow stations, the others arranged in order of increasing rates are (for the summer period June to November), after the hammock forest, the Spanish oak-post oak forest, the flatwoods, the beech (grazed), the short-leaved pines, the scrub oaks, and long-leaved pines. The order, by winter average rates, is flatwoods, short-leaved pines, scrub oaks, Spanish oak-post oak, beech (grazed), and long-leaved pines. The order during the critical period of the year, from January to May (a dry period and a time of sharply rising temperature, corresponding to the time of vernation of the deciduous trees and of changes of leaves, in part or altogether, of many evergreens), is as follows: mesophytic hammock forest, Spanish oak-post oak forest, beech wood (grazed), short-leaved pine wood, long-leaved pine wood, and scrub oaks. Of these the order of the forests on the clayey soils of the upland is essentially that observed for their succession, the difference in winter being in the place of the leafless Spanish oak-post oak forest as compared with the conifer forest. In the pine and oak forests on the dry sandy soils, the same relation

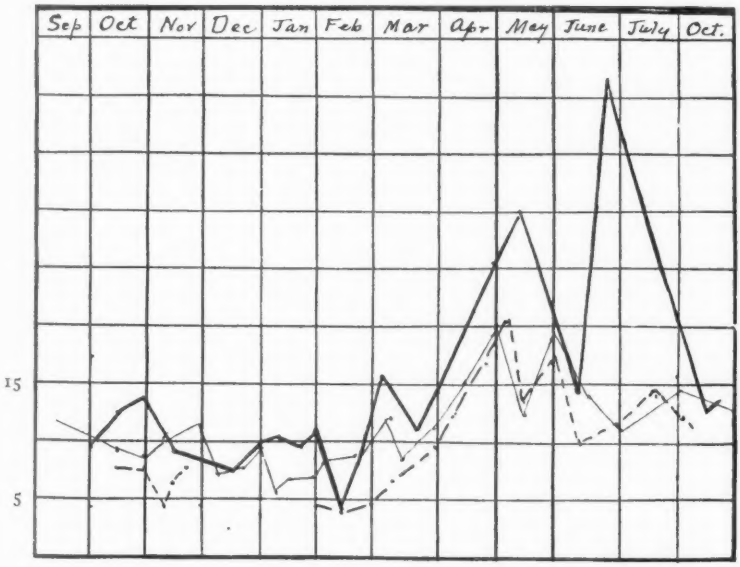

FIG. 3.—Chart showing evaporation rates of 3 pine forests: long-leaved pine on dry sand (heavy line); long-leaved pine on wet sand (broken line); short-leaved pine (light line).

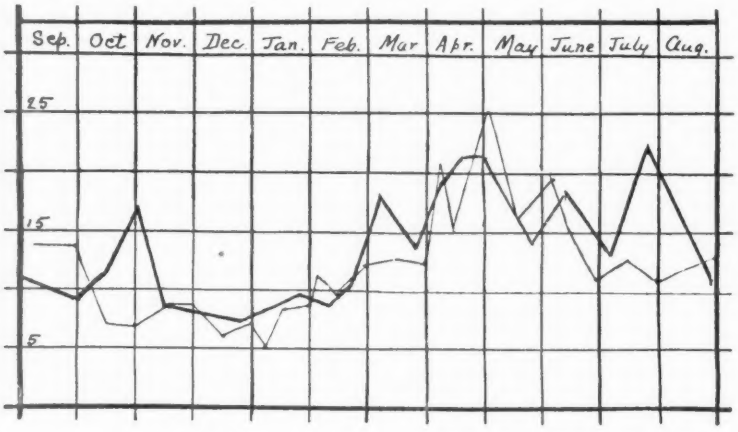

FIG. 4.—Chart showing comparison of evaporation rates, during same year, in the 2 oak forests: scrub oaks (heavy line); Spanish oak-post oak forest (light line).

holds, the oaks showing a higher winter rate than the pines. The two pine forests (short-leaved and long-leaved) on dry soil are nearest together in their evaporation rates during the spring. A comparison of the three pine associations and the two oak associations as charted will show these relations (figs. 3, 4).

The Leon Sand forest is singular in that it is so directly related to the soil moisture, and although all other factors tend to make the evaporation excessive, the constant humidity near the soil surface of the ground, owing to the soil saturation, modifies the curve until it is the most equable of any of those described in this report.

RICHMOND, IND.

FATS FROM RHUS LAURINA AND RHUS DIVERSILOBA[1]

JAMES B. MCNAIR

(WITH ONE FIGURE)

STEVENS (12) has noticed that the green fruit of *Rhus radicans* is very poisonous. STEVENS and WARREN (13), when investigating the fruit of *R. vernix*, found the green fruit highly toxic, while the ripe fruit is harmless. WARREN (15) attributes this interesting change in toxicity to an apparent replacement of acrid resins by wholesome and palatable fats. Besides these species of *Rhus*, a fat (Japan wax) has been found in 4 species of *Rhus: R. succedanea* L., *R. acuminata* DC., *R. vernicifera* DC., and *R. sylvestris* Sieb. and Zucc. (6). All 6 of these species are poisonous, and it is interesting to note that the discovery of fat in the fully matured fruit of *Rhus laurina* Nutt. may add a non-poisonous species to the list.

Investigations were begun by me on the fats from *Rhus laurina* Nutt. and *R. diversiloba* T. and G. with two objects in view: (1) to discover whether or not these fats are identical with Japan wax, and (2) to determine, if possible, the connection between this fat and the poisonous property of *R. diversiloba*. This latter problem appeared all the more interesting when the fact became apparent that during the ripening of the drupes their poisonous properties simultaneously decreased with their increase in fat. When the fruits have reached full maturity (when the semi-transparent epidermis loosens and easily falls off from the waxy mesocarp) they are non-toxic. The toxicity was tested by thoroughly rubbing the pulverized fruits, as well as an alcoholic solution from them (concentrated to one-third of the original volume of the fruits), on the skin of a sensitive person.

The fats experimented with were obtained by boiling the ripe fruits in 95 per cent alcohol under a reflux condenser. The fat samples were purified by repeated solution, evaporation of the

[1] Contribution from the Rudolph Spreckel's Physiological Laboratory of the University of California.

solvent, and crystallization of the solid matter. The substances thus purified are pale yellow, hard, with a conchoidal and somewhat lustrous fracture. Their odor recalls that of tallow and beeswax. Under the microscope they appear to consist of small and large refractive grains. They are insoluble in water, slightly soluble in cold 95 per cent alcohol and ether, easily soluble in hot 95 per cent alcohol (separate on cooling to granular crystalline

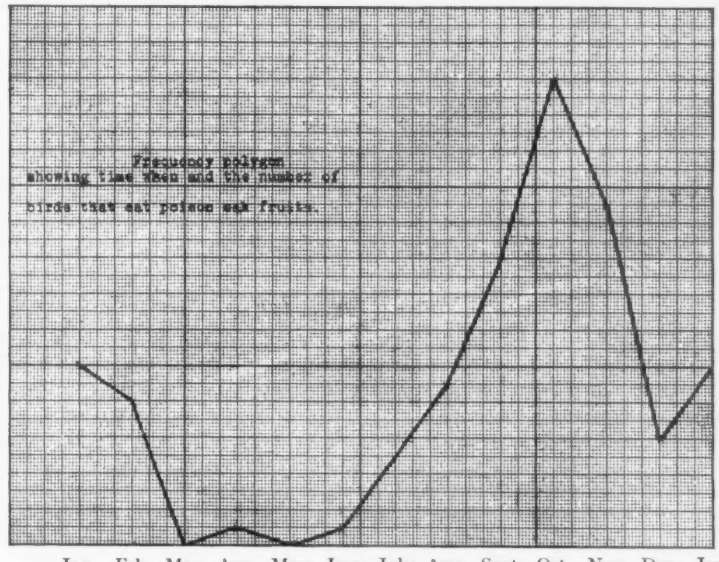

FIG. 1

mass), warm ether, benzol, petroleum ether, and carbon bisulphide. They form grease spots when melted on filter paper. That glycerol is probably a constituent is evident from an irritating odor of acrolein evolved when the substances are mixed with powdered potassium bisulphate and heated in a dry test tube.

From a consideration of their physical and chemical properties so far determined, the fats from *R. laurina* and *R. diversiloba* seem to be similar to Japan wax. This means that similar fats have been found in a non-poisonous and a poisonous species of *Rhus*.

The wide variance in the physical and chemical constants of Japan wax obtained by different experiments, and different experiments by the same investigators, may have been due to several factors, namely, adulterations of water, starch, oil of *Perilla ocimoides* Linn. (BRANNT 2), tallow (BRANNT), the fact that the fat becomes transparent below its fusing point (18–23.5° F. below m.p., BRANNT), the fact that the melting point becomes higher with the age of the sample (BRANNT), impurities, and different methods of analysis.

TABLE I

ANALYTICAL FIGURES OBTAINED

	R. diversiloba	*R. laurina*
Specific gravity...	0.9872 18°.5 C	0.8987 18°.5 C
Solubility*.....	170	136
Iodine absorption.	8.79 per cent (Hübl.)	11.44 per cent (Hübl.)
Saponi value†....	220.6	157.1
Melting point....	53° C.	74° C.

* Mg. per liter in 95 per cent alcohol at 20° C.
† Mg. KOH per gm.

Morphology of fruit of R. diversiloba in relation to fat formation

The ripe fruit of *R. diversiloba* is oval, 5–9 mm. broad, 4–6 mm. high, and 4–6 mm. thick. When first formed it has a shining grass-green color and smooth texture. When dry it becomes brown and presents long dark stripes which previously were only slightly indicated. The outer surface of these stripes is depressed because of the collapsing of the large resin ducts which lie directly beneath them. The outer layer of the fruit, which is a drupe, is something over 1 mm. thick. In the horizontal cross-section 20–30 large resin passages are present. These form a single outer row completely around, which conforms with the general outline of the drupe. Many smaller resin ducts are present, which alternate with the wider ones to form a row next to the seed. The arrangement on the top and bottom of the drupe is less regular. The epidermis is bordered by 2 or 3 layers of strong sclerenchymatous cells. Between these border layers and the resin passages lies the parenchymatous tissue whose cells for the most part contain solid fat. In

the ripe fruit the fat appears in the principal tissue of the mesocarp. Fat is not found in the exocarp, the thin walls and the inner boundary of the mesocarp, the sclerenchymatous cells, the cells of the vascular bundles and their sheaths, and the parenchymatous sheaths of the resin passages.

The presence of solid fat in the fruit cannot be detected before July. At the beginning of August fat formation is nearly completed. The granulated layer of fat can be seen in the cell between the membrane and the protoplasm. This layer makes the lumen smaller, increases on the outside, and goes in between the already formed fat. Its granular form changes to striated masses. Before the formation of this fat in the fruit a progressive increase in the starch content is noticeable. Starch forms partly in the chromatophores in the cell and partly in the cells. When the fruit cells are rich in starch the cells contain besides only granular protoplasm and nuclei. This starch gives a positive reaction with iodine. When fat formation is near completion no starch can be detected in the fruit. In fruits which have nearly completed their growth the resin passages are everywhere constricted by the growth of parenchyma sheaths. From a consideration of these phenomena fat is apparently formed from starch and not from the resin-like poisonous sap.

This view does not seem untenable, for it has been proved that in the storage foods of plants carbohydrates and fats are interchangeable, and in certain cases carbohydrates are entirely replaced by fats. Starch is stored in potatoes and in the tubers of dahlia, and cane-sugar is stored in beet root; the seeds of the two former plants contain oil, while those of the beet are starchy. Although the grains of most grasses contain starch, some instances are known in which fatty oil is present instead (*Phragmites communis*, *Koeleria cristata*, etc.). In the cotyledons of *Impatiens Balsamina* amyloid is stored in the form of enormously thickened walls, while in other species of *Impatiens* the tissue of the cotyledon is thin-walled and oil is present instead of reserve cellulose.

The change of carbohydrates to fats in the seeds of plants has been studied by SCHMIDT (11), LECLERC DU SABLON (4), and others. These investigators have shown clearly that as the

carbohydrates decrease in seeds the fat increases. For instance, when almond seeds first begin to ripen, they are rich in carbohydrates and poor in fats; when fully matured, however, they are poor in carbohydrates and rich in fat. The seeds of *Ricinus* and *Paeonia* are also typical cases. It seems as though the oil in the mature *Ricinus* seed comes from glucose, while that of the *Paeonia* is formed from starch. As it is possible for the plant to translocate fat as such, provided it be an emulsion sufficiently fine, or in the form of fatty acids and glycerine, it might appear to some that the fats in seeds have not been formed *in situ*, but have been conveyed there by the sap. It cannot be denied that translocation of fat may occur to a certain extent; but it is a fact that fats will appear as the carbohydrates disappear in immature seeds even when removed from the parent plant. This fact, when considered with the facts known regarding the formation of fats in vegetative organs under the influence of cold, leads to the inevitable conclusion that fats are formed at the expense of carbohydrates and that this transformation may occur *in situ*.

SCHMIDT (11) and LECLERC DU SABLON (4) have shown conclusively that during the germination of oily seeds a reversal of this process takes place, carbohydrates being formed apparently from fat.

The processes by which carbohydrates are changed to fat are still unknown. As the carbohydrates do not contain such complicated carbon chains as the fats, the formation of fat from carbohydrates must consist of a synthesis, in which the CHOH group is converted into CH_2; hence a reduction must occur.

The formation of fat from carbohydrates in the plant has its parallel in the animal. The great influence of carbohydrates on fat formation in the animal was observed and proved by LAWES and GILBERT (5), VOIT (14), LUMMERT (7), and many others by means of a series of nutrition experiments with different animals, with foods especially rich in carbohydrates, who have apparently proved that a direct formation of fat from carbohydrates does actually occur.

The fat of the poison oak fruit is not a reserve food supply for use of the cotyledon; this is shown by morphology and sprouting.

When the drupe is planted, the growing embryo does not utilize the fat, as it remains unchanged. The fat, however, may be of service to the seed as a protection against cold on account of its low power for heat conduction, increasing its chance of dispersal by streams, as it is far lighter than starch (specific gravity of starch 1.56, fat 0.9872); as a protection from rain and humidity; as a protection from fungi (PFEFFER **9**); and as an attraction to birds and therefore a factor in seed dissemination. The ripe fruits persist on the plant during the winter, long after the leaves have fallen, some until May. Birds, therefore, can see them for a long distance. When eaten, the fatty covering of the drupe only is digested; the ejected seeds can still germinate. MÖBIUS (**8**) has observed the fruits of *R. vernicifera* eaten by half-wild pigeons at Frankfurt. REINECKE (**10**) has recorded the doves of Samoa as eating the fruit of *R. tahitensis*. BARROWS (**1**) speaks of the consumption of the fruit of *R. venenata* and *R. Toxicodendron* by the crow. After eating the fruits the crow rapidly digests the nutritious pulp and ejects from the mouth (in less than 40 minutes after eating) the seeds clean and devoid of pulp, together with the sand swallowed to aid in digestion. Of these ejected seeds 90 per cent germinated.

BRYANT (**3**) has observed that the favorite food of the roadrunner (*Geococcyx californianus*) during the winter season consists of the fruit and seeds of *R. integrifolia*. Unlike many birds which turn their attention to vegetable food during the winter season, the roadrunner appears to discriminate as to the kind of seeds taken. Of the stomachs examined, those of 26 (31.3 per cent) contained the seeds or fruit of *R. integrifolia*, and 8.4 per cent of the food taken by all the birds was made up of this element. The attention of the roadrunner is apparently attracted to this vegetable food only during the winter season, when insects, lizards, and other kinds of food are least abundant.

Summary

1. Substances more similar to Japan wax than to any other fat have been isolated from the ripe fruit of *R. laurina* and *R. diversiloba*.

2. A decrease in the poisonous properties of the fruit of *R. diversiloba* occurs simultaneously with the increase in fat content.

3. The decrease in the poisonous properties in the ripening of the fruit of *R. diversiloba* eventually results in the fruit becoming non-toxic. This phenomenon is not necessarily due to a chemical transformation of the poison into fat for: (a) subsequent to the formation of fat the cells in which it is deposited become filled with starch; (b) it is possible for the plant to transform starch into fat; (c) fat is not formed in the parenchymatous sheaths of the resin passages; (d) consequent upon the formation of fat, the resin passages are everywhere constricted by the growth of parenchyma sheaths; (e) a similar fat has been found in the fruit of a non-poisonous species of *Rhus*.

I am indebted to Professor T. BRAILSFORD ROBERTSON for having placed the resources of his laboratory at my disposal during this investigation.

PASADENA, CAL.

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CURRENT LITERATURE

NOTES FOR STUDENTS

Crown gall.—Recent developments in the study of crown gall and its relation to animal cancer have been presented by SMITH in several papers. The first[1] of these, in point of completion although not in time of publication, is a succinct account of remarkable growth phenomena resulting from the action of *Bacterium tumefaciens* when inoculated into special tissues of plants. Four cases are distinguished.

1. When the internodal cambium is inoculated, this tissue loses its tendency to form mature structures having definite orientation. Instead, the cells continue to divide rapidly, forming large masses of mostly embryonic parenchyma within which scattered and irregularly arranged xylem and phloem elements are differentiated. The process recalls that described by LAMARLIÈRE[2] in the galls of *Gymnosporangium* and aptly designated by him as "parenchymatization."

2. When the cortical parenchyma is infected, a somewhat similar development takes place. The cell divisions succeed each other so rapidly that the cells in the proliferating tissue remain small in comparison with the normal parenchyma, and appear to remain continually in an embryonic state. In time, however, there is a tendency to develop vascular elements, and these are then arranged in a more or less well defined stele. The vascular system of such tumors has no connection with that of the stem, consequently the galls soon die from imperfect nutrition and lack of water. The galls of these two types exhibit no external differentiation. They include all the forms of crown gall described in former papers.[3]

3. A more remarkable condition is brought about when the crown gall organism is inoculated into the leaf axils of young growing plants (species of *Pelargonium*, *Nicotiana*, *Lycopersicum*, *Citrus*, and *Ricinus*). The tumors

[1] SMITH, ERWIN F., Crown gall studies showing changes in plant structures due to a changed stimulus. Jour. Agric. Research **6**:179–182. *pls. 18–23*. 1916; see also Le cancer est-il une maladie du regne végétal? Premier Congress Internat. Path. Comp. Vol. II. 1912; Cancer in plants. Proc. 17th Internat. Congress of Medicine. Vol. III. Pathology. London. 1913; Further evidence as to the relation between crown gall and cancer. Proc. Nat. Acad. Sci. **2**:443–448. 1916; Further evidence that crown gall of plants is cancer. Science **43**:871–889. 1916; Chemically induced crown galls. Proc. Nat. Acad. Sci. **3**:312–314. 1917.

[2] Rev. BOT. GAZ. **42**:153. 1906.

[3] Rev. BOT. GAZ. **52**:75. 1911; **55**:257. 1913.

thus produced are covered with abortive leafy shoots or with flower shoots if a flower incept has been disturbed. On tobacco plants these teratoid tumors may give rise to secondary tumors similar in nature. These daughter tumors are connected with the parent growths by tumor strands which are quite different in structure and location from those occurring in galls of the first two classes. The tumor strands heretofore described were found in the Paris daisy. They arise in the region of the primary xylem and consist of parenchyma tissue. The new tumor strand found in the tobacco occurs in the cortex. It consists of a concentric bundle with the xylem surrounded by the phloem. The daughter tumors arise at intervals along the strand and often have all the characteristics of the parent tumor.

4. The last case, even more remarkable, results when the young leaves of tobacco plants are infected with the crown gall organism. From such infections on the midrib and lateral veins tumors arise which produce leafy shoots. These tumors the author regards as akin to teratoid tumors in animals. The fact of their development is another proof that any plant cell not fully matured may retain the capacity for developing the whole organism.

In another paper,[4] written for medical readers, the subject of crown gall is discussed in its relation to the problems of human cancer. The general resemblances in mode of growth, cell multiplication, occurrence of tumor strands, and production of secondary tumors in the two classes of growths are pointed out. The materials presented in this paper are essentially those of earlier papers, together with the new facts of the paper reviewed above. The phenomena, however, are described in greater detail, and considered with special reference to their bearing on animal pathology. Here, as in other cases, the author relies mostly on numerous excellent photographs for the presentation of his evidence.

In explaining his standpoint with reference to the bearing of his work on the problems of animal cancer, the author makes no claim that the causal organism of the crown gall has any relation to human cancer. It is pointed out, however, that this organism induces in plants a set of phenomena which have a striking parallel in the manifestations of animal cancer. Such phenomena are the growth without function shown by gall tissue, the persistently embryonic character of the proliferating cells, the lack of orderly differentiation of the tumor tissues, the existence of tumor strands giving rise to daughter tumors repeating the structure of the parent gall, and the occurrence of galls resembling embryonic teratoids. It is further pointed out that in the crown gall the cell, although apparently possessing invasive capacity,[5] is not itself the parasite, as

[4] SMITH, ERWIN F., Studies on the crown gall of plants; its relation to human cancer. Jour. Cancer Research 1:231–258. *pls. 1–25.* 1916.

[5] It appears that the embryonic tissue of the gall to a certain extent pushes in among the cells of the sound tissue, a phenomenon which distinguishes this growth from other plant galls induced by fungous or animal parasites. The mode of progress

JENSEN thought. On the contrary, the behavior of the cell is due to an invading specific microorganism. These facts, together with the observation that in one case at least (Rous' sarcoma of fowls) the abnormal growth can be produced by some sort of material separable from the cells and capable of multiplying when injected into other tissues, are regarded by the author as greatly advancing the contention that animal cancer is due to an intracellular parasite.

Exceedingly interesting results[6] were obtained in a series of experiments designed to determine the more immediate causes of tumor growth in crown gall. In this investigation the author was guided by the hypothesis that the substances produced in the metabolism of *Bacterium tumefaciens* must be the direct cause of the cell proliferations. To the end of determining the effects of such substances various plants were injected first with compounds which chemical studies had shown to be products of the causal organism, and finally with a large number of other substances.

The first experiments were conducted with ammonia, which in various concentrations was injected into the stem cavity of *Ricinus* and into the fruit cavities of young green tomatoes. The result of these injections was an abundant formation of cushion-like intumescences within the cavities in both cases. Later, proliferations of the same type were obtained by the injection of a large number of other substances, including ammonium salts of organic and of inorganic acids, dilute solutions of the acids themselves, salts, glucose, and saccharose, and in some instances to a slight extent with distilled water. In many cases when the tissues of the pith cavities of *Ricinus* were exposed to weak ammonia vapors from dilute solutions of ammonium phosphate or ammonium carbonate in tubes sealed into the hollow stems, proliferations were produced not only in the cavities containing the reagents but also in many internodes above and below the opened one. The action in these cases, therefore, took place at a distance through thick partitions. The most striking result was obtained from the injection of a 5 per cent solution of ammonium dihydrogen phosphate into a very young internode of *Ricinus*. In this instance the pith cavity became completely filled by the proliferating pith, and from this tissue a complete vascular cylinder was differentiated. The orientation of the new inner cylinder was the inverse of that of the normal cylinder, the phloem being at the center and the xylem occupying the outer region. Such a complete cylinder was observed only once, but in many instances isolated

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of the tumor strand through the tissues is not yet clear. Whether this structure pushes its way through the pith or cortex by apical growth after the manner of the internal roots of lycopods, or whether progress through the tissues is accomplished by successive cell-invasion by the bacteria and subsequent differentiation of the invaded cells into the characteristic tumor strand, has not yet been determined. From study of his stained sections SMITH thinks that both types of invasion occur.

[6] SMITH, ERWIN F., Mechanism of tumor growth in crown gall. Jour. Agric. Research **8**:165–186. *pls. 4–65.* 1917.

concentric bundles were produced in the proliferating pith. In these the phloem was always at the center of the bundle. Such bundles, the author points out, occur normally in the axes of the inflorescence of *Ricinus* and in the nodes. Superficial intumescences similar to those reported by VON SCHRENK[7] were produced on cauliflower by exposure of the plants to vapors of ammonia and of acetic acid mixed with alcohol.

The outgrowths here described all partake of the nature of intumescences frequently observed in plants. In some cases, indeed, as in the instance described of the complete filling of the pith cavity and the subsequent differentiation of a vascular ring, the outgrowth is excessive. This behavior leads the author to the belief that if the stimulus could be continually applied, one would have a condition resulting in the production of tissue masses not unlike those of crown galls. Since in his experiments the outgrowths also resulted from the presence of many substances not the product of parasites, the author is inclined not to attribute the effect to the specific chemical action of any compound, but seeks for an explanation in some property common to all the compounds regardless of chemical composition. Such a common characteristic he finds in their osmotic action, to which, rather than to chemical stimulation, he ascribes their effect. In this connection it is of interest to recall that intumescences have been produced by ATKINSON,[8] Miss DOUGLAS,[9] and STEINER[10] by subjecting plants to conditions increasing water absorption and diminishing transpiration; and by SORAUER, KÜSTER, VON SCHRENK, and others as a result of application of solutions. In the author's own work the intumescences were mostly the result of injection of solutions, but in some instances they resulted from the injection of water. It is improbable that the osmotic disturbances induced by the application or injection of water are the same as those effected by the application or injection of solutions. The fact that the various disturbances produce responses differing only in degree would seem to indicate that the causes determining the formation of intumescences have not yet been fully analyzed into their separate factors. It is not unlikely that different plants react differently in this respect. The experiments of STEINER would seem to indicate that such a possibility exists.—H. HASSELBRING.

Taxonomic notes.—GATES[11] has attacked the genus *Polygonatum*, which he says "has been in a very chaotic condition owing to the lumping of species, the transference of names, and the confusion of North American with European

[7] Rev. BOT. GAZ. **40**:390. 1905.

[8] ATKINSON, G. F., Oedema of the tomato. Cornell Univ. Agric. Exp. Sta. Bull. **53**:77–108. 1893.

[9] DOUGLAS, Miss G. E., The formation of intumescences on the potato. BOT. GAZ. **43**:233–250. 1907.

[10] Rev. BOT. GAZ. **40**:391. 1905.

[11] GATES, R. R., A revision of the genus *Polygonatum* in North America. Bull. Torr. Bot. Club **44**:117–126. *pls. 4–6.* 1917.

species." He recognizes 9 North American species, giving under each the full synonymy and citations of exsiccatae. The amount of change is indicated by the fact that the revision includes a new species combination, a new variety, and 3 new variety combinations.

KOIDZUMI[12] has published some studies of the plants of oriental Asia, describing new species and varieties. Notable among the genera is *Morus*, of which 25 species are enumerated, 4 of which are new.

MOORE,[13] in connection with descriptions of numerous new species of African Compositae, has established a new genus (*Paurolepis*) belonging to the Vernonieae.

NAKAI,[14] in continuing his studies of the flora of Japan and Korea, has described 21 new species, mostly in genera familiar in this country. The completed studies will furnish much additional evidence of the close relationship of the Japanese and North American floras.

PAYSON,[15] in studying the American perennial scapose species of *Draba*, recognizes 26 species, 14 of which are described as new. The new species are from Utah, Nevada, California, Oregon, Idaho, and adjacent Canada.

POVAH,[16] in concluding his studies of *Mucor*, has presented a taxonomic description of the 18 species investigated. In view of the fact that his experimental work showed that the species of *Mucor* are usually plastic organisms, varying especially with the substratum, it seemed desirable to attempt a standardization of cultural requirements, by investigating as many species as possible under the same cultural conditions. The 18 species described were studied from uniform, standard bread cultures, and 6 of them are described as new.

SMITH[17] has described a new genus (*Parasyringa*) of Oleaceae from China.

TRANSEAU[18] has published a list of the algae of Michigan, based chiefly upon collections made by him during the summer of 1915, in connection with the Michigan Biological Survey, supplemented by other collections. Since no work on Michigan algae has been published for a number of years, the records

[12] KOIDZUMI, GENITI, Contributiones ad floram Asiae Orientalis. Bot. Mag. Tokyo **31**:31–41. 1917.

[13] MOORE, SPENCER LEM., Alabastra diversa. XXVII. Jour. Botany **55**:100–106. *pl. 547*. 1917.

[14] NAKAI, TAKENOSHIN, Notulae ad plantas Japoniae et Koreae. XIV. Bot. Mag. Tokyo **31**:97–112. 1917.

[15] PAYSON, E. B., The perennial scapose Drabas of North America. Amer. Jour. Bot. **4**:253–267. 1917.

[16] POVAH, ALFRED H. W., A critical study of certain species of *Mucor*. V. Taxonomic. Bull. Torr. Bot. Club **44**:287–312. *pls. 17–20*. 1917.

[17] SMITH, W. W., Note on *Parasyringa*, a new genus of Oleaceae. Trans. and Proc. Bot. Soc. Edinburgh **27**:93–96. 1916.

[18] TRANSEAU, E. N., The algae of Michigan. Ohio Jour. Sci. **17**:217–232. 1917.

for species are for the most part new to the state. The list includes 226 species, and among them there is a new species of *Oedogonium* (*O. americanum*), and new varieties of *Vaucheria geminata* and *Oedogonium undulatum*.

VAN ALDERWERELT,[19] in continuing his studies of Malayan pteridophytes, has described 27 new species of ferns, among them a new genus (*Campylogramma*), 11 new species of *Lycopodium*, and 7 new species of *Selaginella*.—J. M. C.

Direct reading potentiometers.—The electromotive force of the hydrogen electrode bears a logarithmic relation to the normal hydrogen-ion concentration H+ of the solution. Where large numbers of determinations are concerned, the calculation of the reaction of the solution in terms of normal acidity becomes laborious. An attempt to simplify the process was made by SÖRENSON, who introduced the P_h values. Since the P_h value is the negative logarithm of the hydrogen-ion concentration, the relation existing between these numbers and the usual method of expressing acidity in terms of normality is not always clear.

BOVIE[20] has devised a potentiometer which reads directly in terms of hydrogen-ion concentration. In the original article a full discussion is given of the method of operating the instrument, as well as of the construction of the dip electrode to be used in titrations. This instrument enables the operator to titrate a solution to a definite hydrogen-ion concentration and thus avoid the error due to misjudgment of the end point as found by the indicator method. Another advantage of the instrument is that it makes it possible to titrate two different acids in the same solution or to titrate successively the hydrogen ions of polyvalent acids or acid salts. It also makes possible the titration of such acids as boric acid, which give an end point on the alkaline side of the neutral point of distilled water. The author gives a number of other very useful applications for the instrument. The apparatus is very well adapted for making large numbers of determinations rapidly and with an accuracy sufficient for ordinary purposes.

Using logarithmic resistances instead of the logarithmic scale, BARTELL[21] has devised a similar apparatus, which avoids the sources of error in the BOVIE apparatus and gives a greater accuracy. It is not expected that this type of potentiometer will replace the older forms which are adapted to reading very small potentials.—R. B. HARVEY.

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[19] VAN ALDERWERELT, Capt. C. R. W. K., New or interesting Malayan ferns. 8 and 9. Bull. Jard. Bot. Buitenzorg nos. 23 and 24. pp. 27 and 8. *pls. 4.* 1916 and 1917.

[20] BOVIE, W. T., A direct reading potentiometer for measuring and recording both the actual and total reaction of solutions. Jour. Med. Research **33**:297. 1915.

[21] BARTELL, F. E., A direct reading ionometer. Jour. Amer. Chem. Soc. **39**:630. 1917.

Mottling in citrus leaves.—JENSEN[22] has attempted to see whether there is any relation between mottling of *Citrus* leaves and the supply of nutrient salts necessary for chlorophyll formation. Such was thought possible since the Office of Biophysical Investigations had found that mottling is inversely proportional to the humus content of the soil, and that decomposing organic matter increases the soluble salts in the soil of the groves. The following statements from his summary indicate the results of the investigation: "Judged by a comparison of the average percentages of the inorganic elements determined in healthy *Citrus* leaves and in leaves in the medium stages of mottling, the data obtained did not show that the initial mottling could be accounted for by deficiency in the transfer of the iron, calcium, magnesium, and phosphoric acid from the conducting system of the leaf stem and midrib to the mesophyll tissue. On the other hand, sharply localized yellow areas in old orange leaves contained less of these elements than the adjoining green areas (mostly veins), but whether that relation obtained in the initial stage of mottling was not determined. In very badly mottled *Citrus* leaves there was in general an increase in the percentage of these elements in the conducting tissues, including the leaf stems, indicating difficulty in their transfer to the mesophyll tissues in very advanced stages of mottling, probably because the leaf had become functionless."

The process of mottling is seemingly very complex, involving as it likely does an unusually rapid decomposition of chlorophyll and not merely a cessation in chlorophyll formation. This problem may yield to solution, if at all, only after a many-sided attack. In some of the algae, however, loss of chlorophyll seems to be a direct result of shortage of nitrate supply. Work of this Office seems to exclude this as a possibility in *Citrus* plants, as well as to indicate the complex nature of the process.—WM. CROCKER.

Monocotyledony.—WORSDELL[23] has criticized the reviewer's view of monocotyledony in a paper which "is an astonishing one." In fact, we seem to be mutually astonished, neither being able to understand the reasoning of the other. The paper opens with an account of "an uncommon abnormality," which consists of a "forked coleoptile" in a corn seedling, and this phenomenon is the excuse for the rest of the paper. It may be well to record that this "forked coleoptile" is a very common phenomenon, as all know who have had much to do with corn seedlings in field cultivation.

The author has not realized the facts and significance of zonation, which are fundamental in this connection, and zonation is by no means a "superficial phenomenon." Zonation enables one to realize, for example, that a prominent,

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[22] JENSEN, C. A., Composition of *Citrus* leaves at various stages of mottling. Jour. Agric. Research **9**:157–166. 1917.

[23] WORSDELL, W. C., The morphology of the monocotyledonous embryo and of that of the grass in particular. Ann. Botany **30**:509–524. *figs. 10.* 1916.

projecting stem tip and a meristematic region that later develops such a tip are of the same ontogenetic significance, and therefore that a cotyledonary ring may be lateral even if the stem tip is not organized. The cells that are to organize it later are still apical. It certainly also gives a simpler and more consistent interpretation of the grass embryo than to imagine a cotyledon consisting of such distinct structures as scutellum, epiblast, and coleoptile, distinct in origin as well as in position and appearance. The author disposes of the dicotyledonous embryo of *Agapanthus* as meaning a "progressive" character, from which we are to infer that he still maintains the view that the dicotyledons have been derived from the monocotyledons. We had assumed that this view was no longer under discussion.—J. M. C.

Temperature and viability.—WAGGONER[24] finds that the resistance of radish seeds to high temperature is inversely proportional to the initial water content at the time of heating. At effective temperatures the water content fell with duration of heating. Three different varieties studied showed similar resistance. WAGGONER finds that much of the past work on resistance of seeds to high temperatures lacks precision because the operators allowed the water content to vary greatly during heating. They heated in water in open dishes, in the oven, or in dry corked flasks. The water absorbed or given off by radish seeds during heating as determined by the use of one or the other of these methods goes far to determine their resistance to heat. GROVES[25] has taken care of this source of error by securing his seeds gas-tight in tubes just large enough to hold the 100 seeds, thus leading to a rapid rise of vapor pressure with heating and an equilibrium between the vapor of the air and the water content without measurable water loss. It is interesting to see that radish seeds can be dried down to 0.4 per cent moisture without injury, for EWART[26] has concluded that the sorts of seeds that are most resistant to drying cannot withstand a moisture reduction below 2 or 3 per cent without injury; while *Oxalis*, *Salix*, and *Populus* will not withstand any drying in a desiccator.—WM. CROCKER.

Organic nutrition of plants.—KNUDSON[27] has investigated the influence of certain mono- and disaccharides, added to nutrient media, on the growth of various green plants, as corn, peas, radish, vetch, etc. These plants can absorb through the root system and utilize sugars in growth. The order of the sugars with reference to beneficial effects varied with the kind of plant. Thus with corn grown in the light, the order was glucose and fructose, saccharose, maltose;

[24] WAGGONER, H. D., The viability of radish seeds (*Raphanus sativus* L.) as effected by high temperatures and water. Amer. Jour. Bot. **4**:299–313. *fig. 1.* 1917.

[25] Bot. Gaz. **58**:169–189. 1917.

[26] Ewart, Proceedings and Trans. of the Liverpool Biol. Soc. **10**:185–193. 1896.

[27] KNUDSON, LEWIS, Influence of certain carbohydrates on green plants. Cornell Agric. Exp. Sta. Mem. **9**:1–75. 1916.

while with Canada field peas it was saccharose, glucose, maltose. lactose. Timothy was found to utilize lactose when grown in darkness, but not when grown in light. The influence of the sugars upon the rate of respiration in the vetch was observed, with the result that saccharose, glucose, and maltose accelerate respiration very noticeably, the latter somewhat less than the other two. Galactose was found to be toxic to wheat, peas, corn, and vetch, even at low concentrations; while glucose antagonizes the toxicity of galactose, possibly by rendering the roots impermeable to galactose, or by altering galactose metabolism in such a way as to prevent formation of toxic oxidation products. The author suggests as a general conclusion that soluble organic substances produced from humus during decay may play a more important rôle in the organic nutrition of plants than we have hitherto thought.—CHARLES A. SHULL.

Osmotic pressure in parasite and host.—Using the cryoscopic method, HARRIS and LAWRENCE[28] have studied the osmotic relations between 7 species of Jamaican mistletoes and their 19 hosts. They find that the sap concentration of the chlorophyllous tissues of the parasite is nearly always higher than that of the mature leaves of the host, the parasites showing an average concentration equivalent to 14.43 and the hosts to 13.59 atmospheres of osmotic pressure. This relationship is not a necessary one, however, for in several cases the parasites possessed sap of a lower concentration than their hosts. In such cases it is assumed that the host supplies more than sufficient water to meet its own needs, so that the parasite is not in direct competition with the leaves of the host, but merely secures water from the same transpiration stream. In cases of secondary parasitism, the osmotic pressure increases from host to primary and from primary to secondary parasite. The sap from the stems of leafless species of *Dendrophthora* possesses a lower concentration than that from leaves of species of *Phoradendron* and *Phthirusa*. The meaning of this is not discussed. It may involve differences in the rate of photosynthetic activity in the leafless and leafy forms.—CHARLES A. SHULL.

Galls.—ESSIG[29] calls attention to the introduction of the chrysanthemum gall fly from Europe. This pest was not known in the United States previous to 1915. It causes cone-shaped galls which often distort the shoot beyond recognition, and eventually causes death of the infected parts. It sometimes destroys one-third of the crop.

WELLS[30] gives us a very important study o the galls of the blackberry The purpose of the paper is threefold: (1) a study of the histology of the galls;

[28] HARRIS, J. ARTHUR, and LAWRENCE, JOHN V., On the osmotic pressure of the tissue fluids of Jamaican Loranthaceae parasitic on various hosts. Amer. Jour. Bot. **3**:438–455. 1916.

[29] ESSIG, E. O., The chrysanthemum gall fly, *Diarthronomyia hypogaea* F. Low. Jour. Econ. Ent. **9**:461–468. 1916.

[30] WELLS, BERTRAM W., The comparative morphology of the zoocecidia of *Celtis occidentalis*. Ohio Jour. Science **16**:249–290. *pls. 8*. 1916.

(2) a study of the galls of *Celtis occidentalis;* (3) a comparative study of structures. The work is exceptionally well done and well presented. There are 17 known species of zoocecidia on the *C. occidentalis*. The acarinous and lepidopterous galls are kataplasma in character, and the hemipterous and dipterous galls protoplasma in character. This latter type is more closely comparable to the normal plant parts, but the tissue forms are new. The author very properly suggests that zoocecidology presents a unique field for the study of problems pertaining to the mechanism used in the expression of hereditary characters.—MEL. T. COOK.

Germination of rice.—NAGAI[31] has made rather an extensive general study of the germination of rice, touching many points that have previously been worked out on other seeds. The cutinized inner integument of the ripe fruit is a semipermeable membrane. Such membranes have been found in the fruit walls of many grasses and in the coats of many seeds.[32] Desiccated seeds of rice are not injured by steeping for 24 hours in ether, chloroform, absolute alcohol, acetone, and other substances. This is in accord with the work of BEQUEREL and of SHULL,[33] who have found that the dry coats of many seeds are impervious to such substances, but that, as the water content of the coats rises, they become more pervious. Rice germinates in an extremely low partial pressure of oxygen, yet the germination is abnormal, the hypocotyl growing only under considerable oxygen pressure. Acids and bases show no stimulative effects upon the germination of rice. A few hours of exposure to liquid air does not injure the seeds of rice or buckwheat. Two hours' exposure to 97–98° C. kills *Zea Mays*, but does little injury to rice, especially if it is desiccated.—WM. CROCKER.

Alkalies and salt absorption.—As a phase in the analysis of the effects of alkalies upon the development of plants, BREAZEALE[34] has studied the effect of NaCl, Na_2SO, and Na_2CO_3 upon the absorption of nitrates, phosphates, and potash by wheat seedlings. Up to 1000 ppm. in a nutrient solution they do not affect the absorption of nitrates. In this concentration NaCl does not modify phosphate absorption, but slightly depresses potash absorption. In 1000 ppm., Na_2SO_4 depresses the absorption of potash and phosphoric acid to approximately 70 per cent of that of the checks. In equal mol concentration Na_2CO_3 depresses the absorption of potash to 20 per cent and phosphoric acid to 30 per cent normal. With Na_2SO_3 these depressing effects were evident in 300 ppm. The writer thinks the depressing effect of the Na_2SO_4 is due to its

[31] NAGAI, ISABURO, Some studies on the germination of seeds of *Oryza sativa*. Jour. Coll. Agric., Imperial University Tokyo **3**:109–155. 1916.

[32] BOT. GAZ. **56**:169–199. 1913; **63**:373–397. 1917.

[33] BOT. GAZ. **56**:169–199. 1913.

[34] BREAZEALE, J. F., Effect of sodium salts in water cultures on the absorption of plant food by wheat seedlings. Jour. Agric. Research **7**:407–416. 1916.

reaction with $CaCO_3$ of the substratum, thus forming Na_2CO_3. Extensive studies of this sort can add much to our knowledge of the absorption of salts by plants and the intereffects of salts upon each other as regards absorption.—WM. CROCKER.

Calcium compounds of the soil.—Under this title[35] E. C. SHOREY, W. H. FRY, and W. HAZEN, members of the Bureau of Soils, have analyzed 63 soil samples of 23 types from 24 locations of 19 states. They have calculated the percentage of calcium combined with humus compound, calcium carbonate, calcium sulphate, and calcium as difficultly and easily decomposed silicates. They find a wide variation in total calcium content and in calcium carbonate and the two classes of silicates, and there was no constant relation between the total calcium content and the percentage of any of the calcium compounds. Calcium combined with humus compounds was absent in 29 soils. One type which is recognized as a good alfalfa soil is characterized by high calcium content, but low content of calcium carbonate. This indicates, as does other evidence, that alfalfa requires a rather high content of calcium ion as a nutrient or balancer of the soil solution, rather than merely calcium carbonate as a neutralizer of acidity.—WM. CROCKER.

Phylogeny of ferns.—BOWER,[36] in continuation of his phylogenetic studies of the ferns, has developed some interesting conclusions in reference to what he calls the "acrostichoid condition," meaning the spreading of exposed sporangia "uniformly over a considerable area of the sporophyll." This fact was the basis of the old genus *Acrostichum*, which BOWER has come to regard not as a natural genus, but as a state or condition which may have been attained along a number of phyletic lines. In the present paper he has presented a number of genera which he regards as "dipterid derivatives," that is, derived from a phyletic stock characterized by *Dipteris*, which show various stages of advance toward the acrostichoid condition. According to this view, a number of so-called genera of ferns are form genera, not being what BOWER calls "phyletic unities." The increasing evidence of parallelism in evolution is raising the question of "phyletic unity" in connection with all of our larger genera.—J. M. C.

Pine forests of Virginia and the Carolinas.—HARPER[37] recently devised a method for securing a rough quantitative analysis of vegetation from notes taken at frequent intervals from the car window or while walking through the country. He made such notes during 53 hours of railroad travel and 21 hours

[35] Jour. Agric. Research **8**:57–77. 1917.

[36] BOWER, F. O., Studies in the phylogeny of the Filicales. VI. Ferns showing the "acrostichoid" condition, with special reference to dipterid derivatives. Ann. Botany **31**:1–39. *pls. 1, 2. figs. 15.* 1917.

[37] HARPER, R. M., Geography and vegetation of northern Florida. Ann. Rep. Fla. Geol. Survey **6**:163–437. 1914.

of walking in Virginia and the Carolinas. To obtain the relative abundance of species in the area involved[38] he counted the number of times each species was mentioned in the notes, and multiplied the figures for *Pinus Taeda* and *P. palustris* by 5, and for the other conifers by 3 before calculating the percentages. The figures for smaller trees were divided by 2 or by 10, for shrubs by 100, and for herbs by 500. The results were tabulated and are rather interesting. Some estimates of annual increment of the whole vegetation, of the amount of mineral matter taken each year from the soil, and of the amount of water transpired are based upon these analyses.—GEO. D. FULLER.

Forest sanitation.—In a recent bulletin MEINECKE[39] emphasizes the importance and also the difficulties of giving phytopathology a proper place in forest regulation. He elaborates methods of investigation and application, exemplifying by an actual study of *Abies concolor*. Forest sanitation is the keynote of the remedial measures proposed, a system of forest regulation which will give proper attention to the removal or destruction of diseased individuals from the community.

It is also interesting to note that WEIR,[40] after discussing the character and nature of the injuries due to various mistletoes, outlines methods of forest sanitation consisting of directing cutting so as to effect the removal of diseased communities and individuals. Such methods of forest sanitation he believes will become increasingly practicable with the increasing demand for cutting privileges in the National Forest Reserves.—GEO. D. FULLER.

Michigan sand dunes.—In a recent bulletin SANFORD[41] estimates that sand dunes stretch for over 400 miles along shore lines of the state of Michigan and cover not less than 550 square miles of its territory. In the southern peninsula, with the removal of the forests, many of the dunes are becoming active again and now constitute a menace to valuable fruit growing lands. The importance of maintaining a forest cover is pointed out, and the various recognized methods of dune reclamation are described. The failure of certain efforts to control dune movement by planting is shown to be due to a discontinuance of work before the final cover of permanent forest growth becomes established. Such plantings made by the government at Manistee in 1902 resulted in a temporary cover, which a small amount of subsequent planting

[38] HARPER, R. M., A quantitative, volumetric, and dynamic study of the vegetation of the *Pinus Taeda* belt of Virginia and the Carolinas. Bull. Torr. Bot. Club **44**:39–57. 1917.

[39] MEINECKE, E. P., Forest pathology in forest regulation. U.S. Dept. Agric. Bull. 275. pp. 63. 1916.

[40] WEIR, J. R., Some suggestions on the control of mistletoe in the national forests of the northwest. Forest Quart. **14**:567–577. 1916.

[41] SANFORD, F. H., Michigan shifting sands: their control and better utilization. Mich. Agric. Coll. Exp. Sta. Bull. 79. pp. 31. *figs.* 22. 1916.

would have converted into a permanent forest. A neglect of this attention resulted in the complete failure of the project.—GEO. D. FULLER.

Nitrogen relations of semi-arid soils.—MCBETH[42] finds that semi-arid soils fail to nitrify dried blood when it is added in 1 per cent quantities. Under the conditions ammonia accumulates in the soil and 50 per cent of the nitrogen may be lost to the air (probably as ammonia) within 6 weeks. When added at ordinary fertilizer rates nitrification is complete. With green manures, especially legumes, nitrification is rapid. Fifty per cent of the nitrogen of the green manure is transformed to nitrates in 30 days. Furrow irrigation leads to the accumulation of the larger part of the nitrate in the surface 6 inches of the soil, and this often results in niter spots. Overhead or basin irrigation gives far better results. Mottled orange leaves show higher water content than checks, and extreme mottling is often, yet not invariably, associated with high nitrate content.—WM. CROCKER.

Effect of dust on photosynthesis.—The effect of surface films and dusts on physiological processes in plants has aroused considerable interest in recent years. California citrus vegetation in the neighborhood of cement works becomes covered with cement dust. Since the dry season lasts several months, the dust remains on the leaves for long periods. YOUNG[43] took advantage of this fact to determine the effect of dusts on carbohydrate synthesis. He found that the cement dust in some cases shuts out as much as 80 per cent of the light from the upper surface of the leaf, but this high exclusion of light did not interfere with carbohydrate synthesis. This work bears out in a practical and interesting way that of BROWN and ESCOMBE in showing the small amount of light that is really necessary for carbohydrate synthesis.—CHAS. O. APPLEMAN.

Nitrogen fixation.—The question of nitrogen fixation by filamentous fungi has been investigated by DUGGAR and DAVIS[44] with reference to *Aspergillus niger*, *Macrosporium commune*, *Penicillium digitatum*, *P. expansum*, *Glomerella Gossypii*, and *Phoma Betae*. Of these, *Phoma Betae* was the only form which was definitely shown to be capable of fixing free nitrogen. The quantities fixed by this fungus varied from 3.022 to 7.752 mg. per culture of 50 cc. of solution when sugar beet or mangel decoction with added sugar were used as culture media. The authors give a critical review of all the available literature on the subject, and in their own work exercised every precaution to avoid the errors and faulty methods which have led to the numerous conflicting results in the investigations of this problem.—H. HASSELBRING.

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[42] MCBETH, I. G., Relation of the transformation and distribution of soil nitrogen to the nutrition of citrus plants. Jour. Agric. Research **9**:183–252. *figs. 19.* 1917.

[43] YOUNG, H. D., Studies on the relation of cement dust to citrus vegetation. I. The effect on photosynthesis. Biochem. Bull. **5**:95–100. 1916.

[44] DUGGAR, B. M., and DAVIS, A. R., Studies in the physiology of the fungi. I. Nitrogen fixation. Ann. Mo. Bot. Gard. **3**:413–437. 1916.

Himalayan vegetation.—Among the matters of botanical interest STEWART[45] has emphasized is the absence of all luxuriant tropical vegetation from this part of India, the indigenous flora being rather of the desert and scrub types. Perhaps the most interesting thing concerning this little known region is the similarity of the forests on the north side of the mountains to those of the eastern United States, as shown by the abundance of trees of such familiar genera as *Pinus*, *Picea*, *Abies*, *Taxus*, *Juglans*, *Betula*, *Ulmus*, *Prunus*, *Acer*, *Quercus*, *Populus*, and *Berberis*. Set in strong contrast are the most abundant genera upon the corresponding southern slopes. This aggregation includes *Acacia*, *Capparis*, *Tamarix*, *Zizyphus*, *Melia*, *Albizzia*, and *Olea*.—GEO. D. FULLER.

Mycorrhiza of Marattiaceae.—WEST[46] has made a careful study of the life history, host relations, and systematic position of a fungus long known to be present in the roots of the Marattiaceae. It is one of the Phycomycetes, and most nearly approaches *Phytophthora* in such characters as are available, but the sexual organs were not observed. WEST has established a new genus (*Stigeosporium*) to include it. No injury to the cells of infected roots by the parasite could be recognized, and the resting spores, with their oily contents, are also formed at the expense of the host. "The advantage of the association is almost entirely on the side of the fungus, the host plant thriving in spite of the presence of the endophyte."—J. M. C.

Cambium in monocotyledons.—Mrs. ARBER[47] has brought together the scattered observations of the occurrence of an ephemeral intrafascicular cambium in monocotyledons, and records also some new observations. It is clear that such a cambium occurs more widely among monocotyledons than has been generally supposed. To the previously recorded cases she adds the inflorescence axes of *Eremurus himalaicus* and *Nothoscordum fragrans*, and the young shoots of *Asparagus officinalis*. The widespread occurrence of this "vestigial, intrafascicular cambium" is a strong additional argument in favor of the derivation of monocotyledons from dicotyledons.—J. M. C.

Seedling anatomy of Ranales.—Miss BLACKBURN[48] has investigated the seedling anatomy of a large number of the Ranales, chief attention being given to the Ranunculaceae. The results of chief phylogenetic interest are the

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[45] STEWART, RALPH R., Some observations on the flora of northwest Himalaya. Torreya **15**:215–260. *figs. 4.* 1915.

[46] WEST CYRIL On *Stigeosporium Marattiacearum* and the mycorrhiza of the Marattiaceae. Ann. Botany **31**:77–99. *pl. 3. figs. 9.* 1917.

[47] ARBER, AGNES, On the occurrence of intrafascicular cambium in monocotyledons. Ann. Botany **31**:41–45. *figs. 3.* 1917.

[48] BLACKBURN, KATHLEEN B., On the vascular anatomy of the young epicotyl in some Ranalean forms. Ann. Botany **31**:151–180. *pl. 13. figs. 19.* 1917.

general prevalence of the trilacunar trace in the seedlings, and the almost universal occurrence of a single ring of bundles connected at a very early age by cambium. This interfascicular cambium is usually absent in the adult stems of the herbaceous Ranunculaceae, but it is invariably present at some stage in the seedling. The evidence of the origin of herbs from woody plants is increasing.—J. M. C.

Germination of ascospores.—BRIERLY[49] has experimented with the germination of the ascospores of *Onygena equina*, a fungus occurring on decomposing horns and hoofs of cattle, sheep, etc. The results showed that "ripe" ascospores will germinate directly after a prolonged resting period, and that this period may be curtailed or eliminated by treating the spores with artificial gastric juice, but not by subjection to low temperatures. "The full-grown unripe ascospores and the chlamydospores will germinate immediately in the absence of digestive treatment."—J. M. C.

Respiration.—APPLEMAN[50] has investigated quantitatively the relation of oxidases and catalase to the process of respiration in potatoes. He found that there was no correlation between intensity of respiration and oxidase activity, but that catalase activity of the extracted juice of the potato shows a close correlation with the respiratory activity of the tuber. He considers, therefore, that the oxidases are not the controlling factor in respiratory intensity, at least in potato tubers, whatever rôle they may have in connection with biological oxidations.—CHARLES A. SHULL.

History of forest ecology.—In a rather extensive review of the literature of botany and of forestry investigations, BOERKER[51] has attempted to trace the influence of both upon the development of the new phase of science known as forest ecology or silvics. Perhaps the most important part of the paper is that in which he traces the ecological principles which were stated by some of the earlier leaders in forestry, but which have received little attention from their fellow foresters. Of almost equal importance is the rather extensive bibliography.—GEO. D. FULLER.

Wandering tapetal nuclei.—PICKETT[52] has described in detail the differentiation of the tapetum and its subsequent behavior in *Arisaema triphyllum*

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[49] BRIERLY, WILLIAM B., Spore germination in *Onygena equina* Willd. Ann. Botany **31**:127–132. 1917.

[50] APPLEMAN, CHARLES O., Relation of oxidases and catalase to respiration in plants. Amer. Jour. Botany **3**:223–233. 1916.

[51] BOERKER, R. H., A historical study of forest ecology; its development in the fields of botany and forestry. Forestry Quarterly **14**:380–432. 1916.

[52] PICKETT, F. L., The wandering tapetal nuclei of *Arisaema*. Amer. Jour. Bot. **3**:461–469. *pl. 20. figs. 8.* 1916.

and *A. Dracontium*. The tapetal cells early show peculiarities of cell wall, cytoplasm, and nucleus. The wall entirely disappears, and the freed protoplasts form a "periplasm" that spreads through the cavity of the sporangium. The forms assumed by the tapetal nuclei, as well as their peculiarities of structure, suggested the possibility of "active migration among the developing pollen spores."—J. M. C.

Vermont trees.—One of the most recent additions to the rather large series of tree manuals is from Vermont.[53] It closely resembles that from Michigan previously reviewed,[54] but it has been revised and modified to meet the slightly different conditions in the new region. There are two sets of keys, one for winter and another for summer use. These, together with the illustrations, should make the identification of any tree an easy matter.—GEO. D. FULLER.

Fossil Sequoia from Japan.—Miss YASUI has[55] described a new species of *Sequoia* (*S. hondoensis*) from a coal field of Japan belonging to the Tertiary. The genus was recognized, not only by its normal structural features, but also by characteristic wound reactions. This discovery adds to the evidence of the wide distribution of *Sequoia* during the Tertiary, and also adds testimony to the assertion that *Sequoia* has descended from the *Pityoxylon* type.—J. M. C.

The vegetation of New York State.—BRAY[56] has compiled a useful description of the vegetation of New York State, seen from the viewpoint of an ecologist. The state is divided into zones according to MERRIAM'S system, and a map showing the modifications of the zones resulting from differences in altitude and the changes due to soil and to proximity to the Great Lakes is produced. The various forest types are well described.—GEO. D. FULLER.

Anatomy of epiphytic orchids.—CURTIS[57] has published a detailed account of the anatomy of 6 epiphytic orchids from New Zealand. Considerable variation is shown in the extent and distribution of the different tissues, and the paper is full of data that will be useful when the anatomy of orchids comes to be organized.—J. M. C.

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[53] BURNS, G. P., and OTIS, C. H., The trees of Vermont. Vt. Agric. Exp. Sta. Bull. 194. pp. 244. *pls. 90*. 1916.

[54] BOT. GAZ. **57**:77. 1914.

[55] YASUI, KONO, A fossil wood of *Sequoia* from the Tertiary of Japan. Ann. Botany **31**:101–106. *pl. 4*. 1917.

[56] BRAY, W. L., The development of the vegetation of New York State. N.Y. State Coll. Forestry, Syracuse Univ. Publ. **3**:pp. 186. *figs. 52*. 1915.

[57] CURTIS, K. M., The anatomy of 6 epiphytic species of the New Zealand Orchidaceae. Ann. Botany **31**:133–149. *pls. 7–12*. 1917.